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THE SUSCEPTIBILITY OF REPRESENTATIVE TACAN AND DME EQUIPMENTS T--ETC(U)

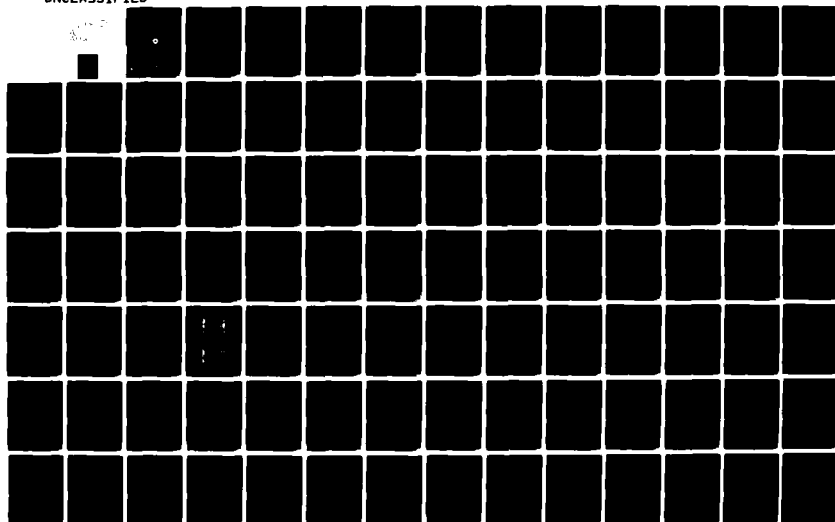
AUG 80 S J SUTTON, G A CHOPAK, G W IMHOF

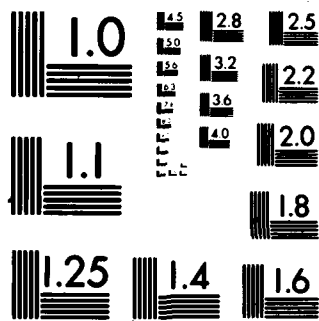
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NATIONAL BUREAU OF STANDARDS-1963-A

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FAA-RD-80-90

LEVEL #1

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**THE SUSCEPTIBILITY OF REPRESENTATIVE
TACAN AND DME EQUIPMENTS TO A PROPOSED,
MLS L-BAND PRECISION DME SIGNAL FORMAT**

**IIT Research Institute
Under Contract to
DEPARTMENT OF DEFENSE
Electromagnetic Compatibility Analysis Center
Annapolis, Maryland 21402**



**August 1980
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16. Abstract → Measured data are presented that show the susceptibility of representative Tactical Air Navigation/Distance Measurement Equipments (TACAN/DME) to the proposed, Microwave Landing System (MLS) L-Band Precision DME (PDME) signal format. The interrogator data are examined to determine the most susceptible equipments, and the desired and undesired signal relationships that permit range and azimuth acquisition. Comments are made on the transponder data. ←					
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PREFACE

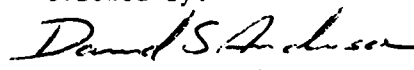
The Electromagnetic Compatibility Analysis Center (ECAC) is a Department of Defense facility, established to provide advice and assistance on electromagnetic compatibility matters to the Secretary of Defense, the Joint Chiefs of Staff, the military departments and other DoD components. The center, located at North Severn, Annapolis, Maryland 21402, is under policy control of the Assistant Secretary of Defense for Communication, Command, Control, and Intelligence and the Chairman, Joint Chiefs of Staff, or their designees, who jointly provide policy guidance, assign projects, and establish priorities. ECAC functions under the executive direction of the Secretary of the Air Force and the management and technical direction of the Center are provided by military and civil service personnel. The technical operations function is provided through an Air Force sponsored contract with the IIT Research Institute (IITRI).

This report was prepared for the Systems Research and Development Service of the Federal Aviation Administration in accordance with Interagency Agreement DOT-FA70WAI-175, as part of AF Project 649E under Contract F-19628-78-C-0006, by the staff of the IIT Research Institute at the Department of Defense Electromagnetic Compatibility Analysis Center.

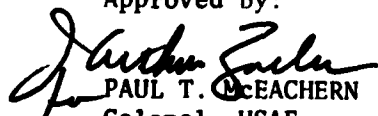
To the extent possible, all abbreviations and symbols used in this report are taken from American Standards Y10.19 (1967) "Units Used in Electrical Science and Electrical Engineering" issued by the USA Standards Institute.



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ENGLISH/METRIC CONVERSION FACTORS

LENGTH

From \ To	cm	m	km	in	ft	mi	nmi
cm	1	0.01	1×10^{-5}	0.3937	0.0328	6.21×10^{-6}	5.39×10^{-6}
m	100	1	0.001	39.37	3.281	0.0006	0.0005
km	100,000	1000	1	39370	3281	0.6214	0.5395
in	2.540	0.0254	2.54×10^{-5}	1	0.0833	1.58×10^{-5}	1.37×10^{-5}
ft	30.48	0.3048	3.05×10^{-4}	12	1	1.89×10^{-4}	1.64×10^{-4}
mi	160,900	1609	1.609	63360	5280	1	0.8688
nmi	185,200	1852	1.852	72930	6076	1.151	1

AREA

From \ To	cm ²	m ²	km ²	in ²	ft ²	mi ²	nmi ²
cm ²	1	0.0001	1×10^{-10}	0.1550	0.0011	3.86×10^{-11}	5.11×10^{-11}
m ²	10,000	1	1×10^{-6}	1550	10.76	3.86×10^{-7}	5.11×10^{-7}
km ²	1×10^{10}	1×10^6	1	1.55×10^3	1.08×10^7	0.3861	0.2914
in ²	6.452	0.0006	6.45×10^{-10}	1	0.0069	2.49×10^{-10}	1.88×10^{-10}
ft ²	929.0	0.0929	9.29×10^{-8}	144	1	3.59×10^{-8}	2.71×10^{-8}
mi ²	2.59×10^{10}	2.59×10^6	2.590	4.01×10^9	2.79×10^7	1	0.7548
nmi ²	3.43×10^{10}	3.43×10^6	3.432	5.31×10^9	3.70×10^7	1.325	1

VOLUME

From \ To	cm ³	liter	m ³	in ³	ft ³	yd ³	fl. oz.	fl. pt.	fl. qt.	gal.
cm ³	1	0.001	1×10^{-6}	0.0610	3.53×10^{-5}	1.31×10^{-6}	0.0338	0.0021	0.0010	0.0002
liter	1000	1	0.001	61.02	0.0353	0.0013	33.81	2.113	1.057	0.2642
m ³	1×10^6	1000	1	61,000	35.31	1.308	33,800	2113	1057	264.2
in ³	16.39	0.0163	1.64×10^{-5}	1	0.0006	2.14×10^{-5}	0.5541	0.0346	2113	0.0043
ft ³	28,300	28.32	0.0283	1728	1	0.0370	957.5	59.84	0.0173	7.481
yd ³	765,000	764.5	0.7646	46700	27	1	25900	1616	807.9	202.0
fl. oz.	29.57	0.2957	2.96×10^{-5}	1.805	0.0010	3.87×10^{-5}	1	0.0625	0.0312	0.0078
fl. pt.	473.2	0.4732	0.0005	28.88	0.0167	0.0006	16	1	0.5000	0.1250
fl. qt.	948.4	0.9483	0.0009	57.75	0.0334	0.0012	32	2	1	0.2500
gal.	3785	3.785	0.0038	231.0	0.1337	0.0050	128	8	4	1

MASS

From \ To	g	kg	oz	lb	ton
g	1	0.001	0.0353	0.0022	1.10×10^{-6}
kg	1000	1	35.27	2.205	0.0011
oz	28.35	0.0283	1	0.0625	3.12×10^{-5}
lb	453.6	0.4536	16	1	0.0005
ton	907,000	907.2	32,000	2000	1

TEMPERATURE

$$^{\circ}\text{C} = 5/9 (^{\circ}\text{F} - 32)$$

$$^{\circ}\text{F} = 9/5 (^{\circ}\text{C}) + 32$$

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**FEDERAL AVIATION ADMINISTRATION
SYSTEMS RESEARCH AND DEVELOPMENT SERVICE
SPECTRUM MANAGEMENT STAFF**

STATEMENT OF MISSION

The mission of the Spectrum Management Staff is to assist the Department of State, Office of Telecommunications Policy, and the Federal Communications Commission in assuring the FAA's and the nation's aviation interests with sufficient protected electromagnetic telecommunications resources throughout the world to provide for the safe conduct of aeronautical flight by fostering effective and efficient use of a natural resource--the electromagnetic radio-frequency spectrum.

This objective is achieved through the following services:

- Planning and defending the acquisition and retention of sufficient radio-frequency spectrum to support the aeronautical interests of the nation, at home and abroad, and spectrum standardization for the world's aviation community.
- Providing research, analysis, engineering, and evaluation in the development of spectrum related policy, planning, standards, criteria, measurement equipment, and measurement techniques.
- Conducting electromagnetic compatibility analyses to determine intra/inter-system viability and design parameters, to assure certification of adequate spectrum to support system operational use and projected growth patterns, to defend the aeronautical services spectrum from encroachment by others, and to provide for the efficient use of the aeronautical spectrum.
- Developing automated frequency-selection computer programs/routines to provide frequency planning, frequency assignment, and spectrum analysis capabilities in the spectrum supporting the National Airspace System.
- Providing spectrum management consultation, assistance, and guidance to all aviation interests, users, and providers of equipment and services, both national and international.

EXECUTIVE SUMMARY

The International Civil Aviation Organization (ICAO) has adopted the Time Reference Scanning Beam (TRSB) Microwave Landing System (MLS) as the standard international, nonvisual, precision approach and landing system. This system uses two frequency bands: 5-5.25 GHz for 200 angle-guidance channels, and 960-1215 MHz for 200 range-guidance channels.

In order to establish the compatibility of the MLS Precision Distance Measurement Equipment (PDME) with the existing and future Tactical Air Navigation (TACAN)/DME, the FAA sponsored a PDME vs TACAN/DME compatibility measurement program in 1976. This analysis contained in this report was undertaken to: 1) present and analyze the results of the PDME vs TACAN/DME compatibility measurement program, and 2) recommend further analyses and measurements regarding PDME vs TACAN/DME compatibility that will assist the FAA to develop a total MLS channel plan.

The PDME signal format currently (1977) being considered consists of a pulse pair: the first pulse is specially shaped, and the second pulse is a standard, Gaussian-shaped TACAN/DME pulse. Using varying pulse-repetition frequencies, signal levels, and pulse-pair spacings, this signal format was introduced as interference to TACAN/DME interrogators and transponders to determine their susceptibility to this interference. The measurements showed that interrogators and transponders are affected by both simulated cochannel and adjacent-channel PDME signals. The effect increased with higher signal rates. For the most susceptible equipment, the effect appeared to be independent of the PDME pulse-pair spacing. The PDME/TACAN signal conditions that precluded interference were similar to the existing TACAN/DME siting criteria. Contrary to common opinion, existing TACAN/DME equipment do not provide sufficient rejection to undesired signals of a different pulse-pair spacing to allow indiscriminate use of pulse-multiplexing in L-Band. These conditions make it no easier to assign PDME channels employing a special channel plan than to employ the existing 252 TACAN/DME channels as long as conventional TACAN/DME remain in the operational environment.

EXECUTIVE SUMMARY (Continued)

Since the data analysis presented in this report is the first step in establishing TACAN/DME and PDME compatibility, recommendations are made for further measurement and analysis. Specifically, a channel assignability analysis is recommended to determine the viability of potential siting criteria and channel plans.

Document is published as a 2 volume set, with volume 2, containing the raw data, available only as microfiche in the envelope on the inside of the back cover of volume 1.

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G	DATA SHEETS FOR THE COLLINS 860E-2	G-1
H	DATA SHEETS FOR THE COLLINS 860E-3	H-1
I	DATA SHEETS FOR THE NARCO DME 190	I-1
J	DATA SHEETS FOR THE AN/GRN-9C	J-1
K	DATA SHEETS FOR THE RTB-2	K-1
L	DATA SHEETS FOR THE KING KN 60C	L-1
M	DATA SHEETS FOR THE KING KN 65	M-1
N	DATA SHEETS FOR THE NARCO UDI4	N-1
REFERENCES		R-1

SECTION 1

INTRODUCTION

BACKGROUND

The International Civil Aviation Organization (ICAO) has adopted the Time Reference Scanning Beam (TRSB) Microwave Landing System (MLS) as the standard international, nonvisual, precision approach and landing system.¹ The TRSB MLS can use the aeronautical radionavigation band of 5.00-5.25 GHz (C-Band) for both the angle- and range-guidance functions. However, an alternate proposal (Reference 1) has been made to use the 960-1215 MHz (L-Band) aeronautical radionavigation band for the TRSB-MLS range-guidance function. The current MLS channel plan allots 200, 300 kHz paired angle- and range-guidance channels in the 5.00-5.25 GHz band. Several channel plans for alternative 200 L-Band, range-guidance channels have been suggested, but no one plan has been accepted by the international community.^{2,3,4}

Though the FAA has stated its preference for the MLS range-guidance function in the L-Band (Reference 1), the ability must be determined for the MLS range-guidance Precision Distance Measuring Equipment (PDME) system to operate in the presence of the existing and future TACAN/DME system without mutual performance degradation. The PDME channel plans that have been proposed

¹*Time Reference Scanning Beam Microwave Landing System, A New Nonvisual Precision Approach and Landing System for International Civil Aviation*, U.S. DOT/FAA, December 1975.

²Hirsch, C. J., *L-Band DME for the Microwave Landing System*, Final Report for the FAA under contract WI-71-3086-1, February 1972.

³*Doppler Microwave Landing Guidance System, A Proposal for a New Nonvisual Precision Approach and Landing Guidance System*, Submitted by the United Kingdom to the International Civil Aviation Organization, November 1975.

⁴*The DME-Based-Landing System, A Contribution of the Federal Republic of Germany, (Proposal for a New Nonvisual Precision Approach and Land Guidance System)*, Bonn, West Germany, September 1975.

for the 960-1215 MHz band apparently have been derived without giving full consideration to susceptibility of TACAN/DME air (interrogator) and ground (transponder) equipments to interference from PDME signals. To determine this susceptibility, the FAA tasked⁵ ECAC to prescribe, monitor, and evaluate measurements that would show the susceptibility of representative interrogators (12 equipments) and transponders (2 equipments) to PDME signals. These tests were conducted by the National Aviation Facilities Experimental Center (NAFEC) between June and December 1976 and were monitored by ECAC.

The FAA then tasked⁶ ECAC to document and analyze all the test data and recommend further measurements and analyses that would assist the FAA to develop an acceptable PDME channel plan.

OBJECTIVES

The objectives of this analysis were to: 1) present and analyze the results of the PDME vs TACAN/DME compatibility measurement program undertaken in 1976, and 2) recommend further analyses and measurements regarding the PDME vs TACAN/DME compatibility that will assist the FAA to develop an acceptable PDME channel plan.

APPROACH

To satisfy the first objective, ECAC compiled all the test data and presented it in both tabular and graphical form. ECAC then examined the data and compared the relative performance of interrogators and transponders. This performance comparison resulted in a relative ranking of equipments based on the susceptibility of each equipment to interference from proposed PDME signals. ECAC then developed general susceptibility characteristics for TACAN/DME equipment when subjected to a PDME signal format.

⁵Interagency Agreement No. DOT-FA70WAI-175, Task Assignment No. 27, Modification No. 3, dated September 1975.

⁶Interagency Agreement No. DOT-FA70WAI-175, Task Assignment No. 27, Modification No. 7, January 1976.

To satisfy the second objective, ECAC developed recommendations for further testing and analyses by considering the measurement plan used for this test program, the results obtained, and the FAA goals.

SECTION 2

MEASUREMENT PROGRAM

PROGRAM DESCRIPTION

The viability of a frequency allocation in L-Band (960-1215 MHz) for MLS PDME depends on: the conditions needed for compatible operation of MLS PDME and TACAN/DME systems, the channel allotment scheme for PDME, and the ability to assign channels to both PDME and TACAN/DME systems in future environments so that these systems can perform their services without the adverse affects of mutual interference.

As a first step toward determining the conditions needed for compatible operation of MLS PDME and TACAN/DME, the FAA initiated a measurement program. Its purpose was to determine the susceptibility of representative TACAN/DME interrogator and transponder equipments to proposed, MLS L-Band PDME signals. The measurements were performed by FAA personnel at the National Aviation Facilities Experimental Center (NAFEC), Atlantic City, New Jersey in 1976. ECAC prepared the measurement program plan, monitored the conduct of the tests, reviewed the test data as it became available, and advised NAFEC on matters pertaining to the test procedures, equipments, and data.

MLS L-BAND PDME SIGNAL FORMAT AND SIMULATOR

The proponents of MLS L-Band PDME envision this capability as an extension of the internationally recognized DME and military TACAN systems.⁷ (See References 1, 2, 3, and 4.) The proposed PDME signal format is a pulse pair similar to the TACAN/DME pulse pair. Since the PDME must provide a ± 100 -foot range accuracy and concurrently must satisfy the ICAO DME standard for the transmitted spectrum,

⁷International Civil Aviation Organization, *International Standards and Practices: Aeronautical Telecommunications, Annex 10 to the Convention on International Civil Aviation*, Volume 1, Montreal, Canada, July 1972 with Amendments through July 1974.

the FAA has proposed modifying the first pulse of the pair so that the leading edge has a cosine shape for a rapid rise time, and the trailing edge a cosine-squared shape, as shown in FIGURE 1a. The second pulse retains the normal TACAN/DME Gaussian shape.

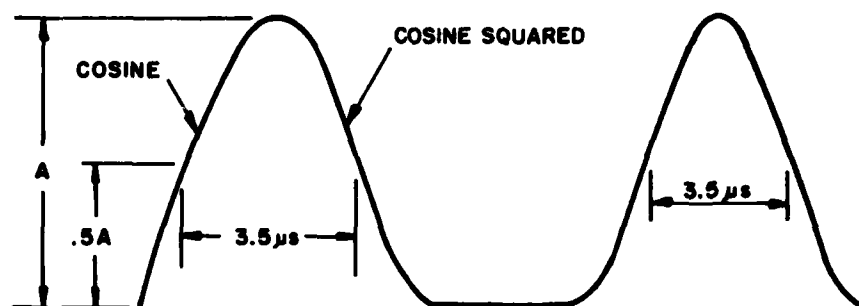
A preferred first-pulse shape had been recommended to the FAA MLS Program Office, based on data presented by Hazeltine Corporation,⁸ and would rise to half its amplitude in 583 ns. However due to test equipment limitations, the pulse shape implemented in the test program is shown in FIGURE 1b. Its rise time is 500 ns, resulting in a broader spectrum. In particular, the spectrum is approximately +8 dB higher at ± 2 MHz than that of the theoretical pulse shape with rise-time of 583 ns. But, as noted in the results of this report, the test conclusions would remain the same had the ideal pulse been used.

The time spacing between the pulses has not been defined. It will depend on whether X- and/or Y-mode channels will be allotted to PDME and on the susceptibility of TACAN/DME equipments to signals with pulse-pair spacings that are not presently employed by TACAN/DME systems (i.e., 12, 30, or 36 μ s). Any new mode of operation that may be implemented for PDME should have a characteristic pulse-pair spacing that minimizes the impact of PDME on TACAN/DME operation and performance.

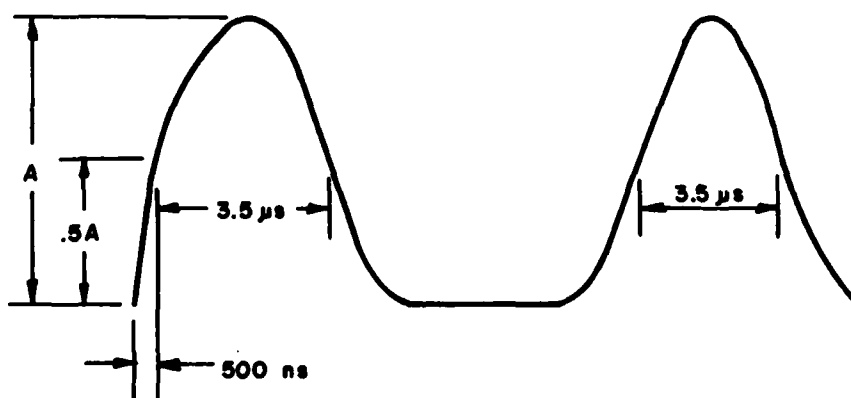
To examine the impact of the PDME format on TACAN/DME equipments, NAFEC needed a simulator that could transmit PDME pulse pairs of any spacing up to 50 μ s, at any rate up to 10,000 Hz, on any frequency in the 960-1215 MHz band, and with received power levels not to exceed -20 dBm.

The simulator that NAFEC constructed, as shown in FIGURE 2, had some of the features of power, pulse repetition frequency (PRF) and spacing variability but could not meet all of the limits specified above. The simulator consisted of the Kustom Electronics SQUAWK/NAUT-I DME Transponder Simulator and added circuitry for shaping the first pulse of each transmitted pulse pair.

⁸Palmieri, C. A., *Evaluation of L-Band DME for MLS*, Report 11083, Hazeltine Corporation, Greenlawn, NY, 20 February 1976.

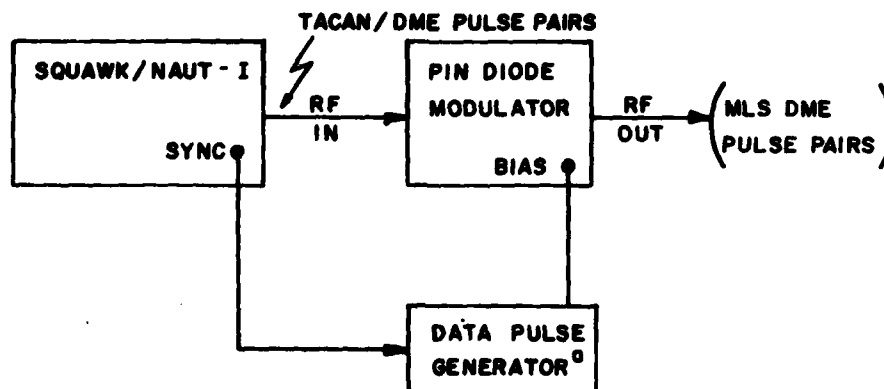


a) As suggested to FAA.



b) As implemented in test program.

FIGURE 1. MLS L-BAND PDME SIGNAL FORMAT.



^aDelays Sync pulse so that output coincides with leading edge of first pulse of pulse pair. Rise and fall time of output pulse was adjusted so that first pulse rises to half-amplitude in 500 ns.

FIGURE 2. PDME PULSE-PAIR SIMULATOR.

The SQUAWK/NAUT-I permitted variance of the pulse-pair spacing only between 7 and 18 μ s, and between 24 and 36 μ s. This required revising the measurement procedures to include only the pulse-pair spacings provided by the simulator. During the transponder susceptibility measurements, attempts to circumvent this problem led to the identification of another limitation of the simulator, the generation of the PRF. The simulator has the capability of transmitting pulse pairs at pseudorandom rates up to 9975 Hz.

The SQUAWK/NAUT-I simulates TACAN/DME transponder transmissions so that the distribution of the pulse-pair repetition period is in accordance with the expected distribution of squitter pulse pairs from a transponder. Therefore, the most frequent spacing between pulse pairs is 60 μ s. When signals from the

simulator are transmitted to a transponder, a pulse pair that follows a decoded pulse pair by 60 μ s will not be decoded because the transponder decoder is still deactivated due to the reply dead time. Since the 60 μ s repetition period is most frequent, fewer decodes are detected for the simulator signal than would be expected with the actual equipment. When signals from the simulator are transmitted to an interrogator, pulse pairs are constantly decoded because the interrogator does not deactivate.

The simulator provided sufficient output power for the interrogator tests but for the transponder tests additional power would have been useful to overcome fixed losses in the test configuration.

INTERROGATOR MEASUREMENTS

The susceptibility of TACAN/DME interrogators to interference was measured in terms of the maximum PDME signal level that permitted range or azimuth acquisition from the desired signal. This signal level was recorded as a function of PDME pulse-pair spacing, PDME PRF, PDME signal frequency, and TACAN/DME desired signal level.

For TACAN interrogators, susceptibility measurements were made for both the range and azimuth capabilities. For measurements where the interfering signal was cochannel with the desired X-mode signal, TACAN interrogators were tuned to channel 1X (962 MHz) and DME interrogators to channel 17X (978 MHz). For cochannel measurements on a Y-mode interrogator, the equipments were tuned to channel 43Y (the first Y-mode channel available on the modified AN/ARN-22). Adjacent-channel measurements were conducted with the equipments tuned to channels 27X or 43Y. The minimum discernible signal (MDS) for each equipment was taken as that specified by the manufacturer.

The AN/ARN-22 TACAN transponder simulator was adjusted to provide the transponder characteristics as shown in TABLE 1.

TABLE 1
SIMULATED TRANSPONDER CHARACTERISTICS FOR
INTERROGATOR MEASUREMENTS

Parameters	TACAN	DME
Frequency (MHz)/Channel	962/1X (988 \pm 10/27X) 1130/43Y (1130 \pm 10/43Y)	978/17X (988 \pm 10/27X) 1130/43Y (1130 \pm 10/43Y)
Reference Range (nmi)	90	90
Reference Azimuth (°)	90	-
Antenna Pattern Rotation	on	off
TACAN Reference Bursts	on	off
Identification Signal	off	off
Signal Level (dBm)	as required	as required
Reply Efficiency (%)	70	70
% 15 Hz and 135 Hz Modulation	20/20	off

Representative TACAN/DME Equipments

NAFEC performed the measurements on three TACAN and nine DME interrogators. TABLE 2 lists the nomenclatures, serial numbers, and manufacturer MDS of these equipments. NAFEC verified acceptable operation of each equipment by obtaining measurements in accordance with ARINC Characteristic 568-4.⁹

Decoder Aperture Measurement

The interrogator decoder aperture defines the set of pulse-pair spacings that can be decoded by the interrogator. The apertures for X-mode and Y-mode operation were measured with both normal TACAN/DME pulse pairs and PDME pulse pairs.

FIGURE 3 shows the measurement configuration for this test. The interrogator was allowed to acquire range lock to a strong desired signal. This

⁹Mark-3 Airborne DME, ARINC Characteristic 568-4, 15 May 1975.

maintains the automatic gain control (AGC) at a specific level and permits the counting of decodes that are synchronous with test input pulse pairs. The test signal at a 150 pulse-pairs per second (pp/s) rate was introduced into the interrogator receiver. The decoder output was gated with the input test signal and a counter recorded the number of replies per second and synchronous with the input signal.

For X-mode equipments, the number of synchronous decodes was recorded for spacings of 7-18 μ s in one microsecond steps, 24 and 36 μ s. This data was taken for test signal levels of MDS, MDS + 10 dB, and MDS + 20 dB. The procedure was similar for Y-mode equipments except the pulse-pair spacing of the test signal was varied between 24 and 36 μ s in one microsecond steps.

TABLE 2

TESTED INTERROGATORS

Nomenclature	Serial No.	MDS (dBm)
TACAN		
AN/ARN-21C	16314	-85
AN/ARN-52(V)	235	-80 (azimuth); -90 (range)
AN/ARN-84	15002	-90
DME		
KING KN 60C	2918	-82
KING KN 65	12797	-85
KING KDM 7000	1349	-90
KING KDM 705A	3032	-82
RCA AVQ-70	1262	-85
COLLINS 860-E2	1182	-86
COLLINS 860-E3	1379	-90
NARCO DME 190	13081	-82
NARCO UDI 4	K-04334C	-75

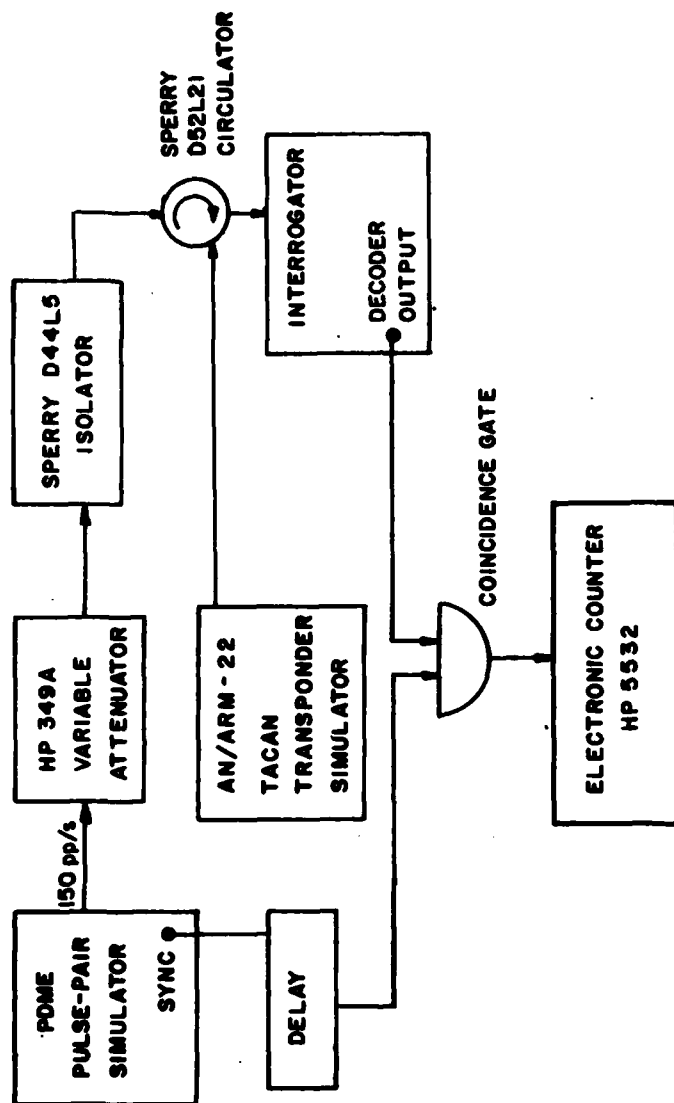


FIGURE 3. DECODER APERTURE TEST CONFIGURATION.

Acquire-Lock Measurement^a

This test was performed for cochannel and adjacent-channel interference signals. The equipment susceptibility to the interfering PDME signal was measured for X-mode and Y-mode desired signals. Both range and azimuth functions for TACAN equipments were examined for susceptibility to the interference from the PDME signals.

FIGURE 4 shows the arrangement of test equipment. The cochannel test procedures were as follows:

1. Set the desired signal at MDS.
2. With no interfering PDME signal present, let the interrogator acquire-lock with the signals from the AN/ARN-22.
3. Set PDME PRF to 1000 pp/s, pulse-pair spacing to 12 μ s (X-mode) or 30 μ s (Y-mode).
4. Increase interfering PDME signal level from below MDS until break-lock occurs. (If the interrogator will not break-lock, intentionally break-lock by changing channels and rechanneling.) Record the PDME power level.
5. Reduce the PDME signal level until lock is reacquired (allow 30 seconds to acquire-lock). Record the PDME power level. This is the maximum interfering signal that will permit lock.
6. Repeat steps 2, 3, 4, and 5 four more times. The valid data points for break-lock and acquire-lock are the ones which are in agreement to within ± 1 dB, 4 of 5 times.
7. Repeat steps 2, 3, 4, 5, and 6 for PDME PRF's of 2700, 5000, and 10,000 pp/s.
8. Repeat steps 2, 3, 4, 5, 6, and 7 for PDME pulse-pair spacings that are on the edge of the decoder aperture and outside the aperture.

The procedure for the adjacent-channel tests was identical to the cochannel measurement tests except consideration was given to only PDME PRF's of 2700 and

^aSee APPENDIX I for test procedure for NARCO DME 190.

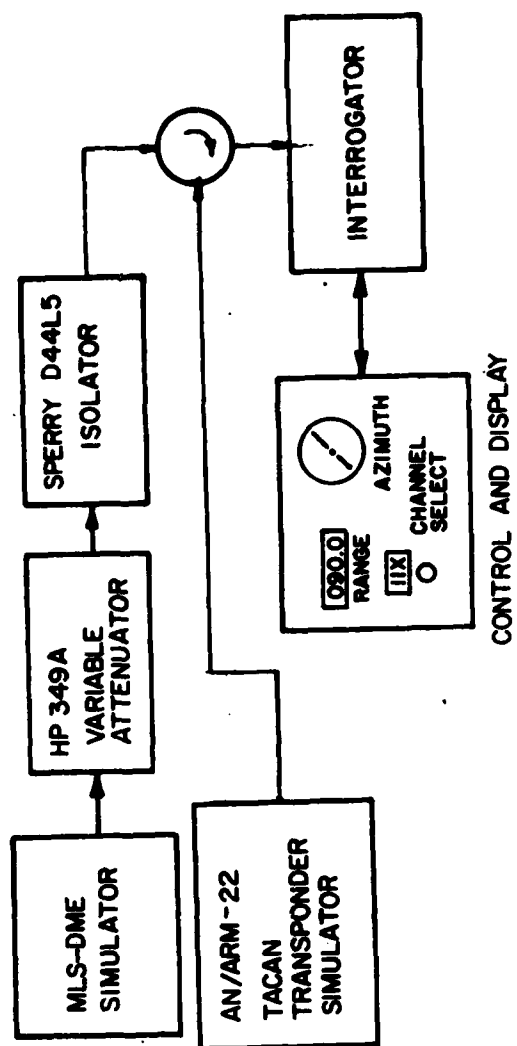


FIGURE 4. ACQUIRE-LOCK TEST CONFIGURATION.

5000 pp/s and to two pulse-pair spacings (X-mode equipment of 30 and 12 μ s, Y-mode equipment of 30 and 18 μ s or 24 μ s). The acquire-lock measurements were performed for frequency separations of 0, ± 0.9 , ± 2 , ± 5 , ± 10 MHz between the desired and undesired signals.

Cochannel Desired Signal Measurement

This test was performed to determine the susceptibility of the interrogators to interference when the desired signal was not at MDS. The cochannel acquire-lock measurements were repeated using desired signal levels of -91 dBm, -78.5 dBm, MDS - 3 dB, and MDS + 6 dB. Only PDME PRF's of 2700 and 5000 pp/s were considered.

TRANSPONDER MEASUREMENTS

The susceptibility of transponders to interference was measured in terms of the reply efficiency to the desired signal with a specific interrogation rate and signal level. The reply efficiency is defined as the reply rate that is synchronous with the desired interrogation rate divided by the desired signal rate. This parameter was measured as a function of desired signal interrogation rate and level and PDME pulse-pair spacing, rate, and signal level.

NAFEC performed measurements on two transponders, the AN/GRN-9C and a modified RTB-2. The AN/GRN-9C is used extensively by the FAA in the TACAN/DME system. However, the model at NAFEC did not have all the necessary field modifications to make it representative of an operational transponder. The modified RTB-2 contained an engineering development model of a receiver built by EDMAC Associates. This receiver is entirely solid state and contains features expected to be implemented in future TACAN/DME transponders. While the AN/GRN-9C operated only in X-mode, the modified RTB-2 had the capability of both X- and Y-mode operation. TABLE 3 gives the measured MDS of these transponders.

TABLE 3
TRANSPONDERS TESTED

Nomenclature	Serial Number	Channel/Frequency (MHz)	MDS ^a (dBm)
AN/GRN-9C	228	114/1138	-96
Modified RTB-2	5.1	27X/1051 27Y/1051	-96

^aBased on 60% reply efficiency for 400 pp/s input.

Decoder Aperture Measurement

The set of pulse-pair spacings that are decodable by the transponder define the decoder aperture of the transponder receiver. The X-mode and Y-mode decoder apertures were determined using both normal TACAN/DME pulse pairs and PDME pulse pairs.

FIGURE 5 shows the measurement configuration for the X-mode decoder aperture test. A test signal at a 150 pp/s rate was introduced into the transponder receiver. The decoder output was gated with the input test signal and a counter recorded the number of replies per second synchronous with the input signal. To determine the aperture of the decoder the pulse-pair spacing of the test signal was varied from 7-18 μ s, in one microsecond steps and set at 24 and 36 μ s. The aperture was measured for test signal levels of MDS, MDS + 10 dB, and MDS + 20 dB.

FIGURE 6 shows the test configuration for the modified RTB-2 Y-mode aperture measurements. Note that the RTB-2 internal generator provided pulse-pairs at the proper spacing which were used as a trigger source for the SQUAWK/NAUT-I which in turn provided the proper PDME waveform as interference. No desired signal was necessary. The procedure was identical to the X-mode aperture

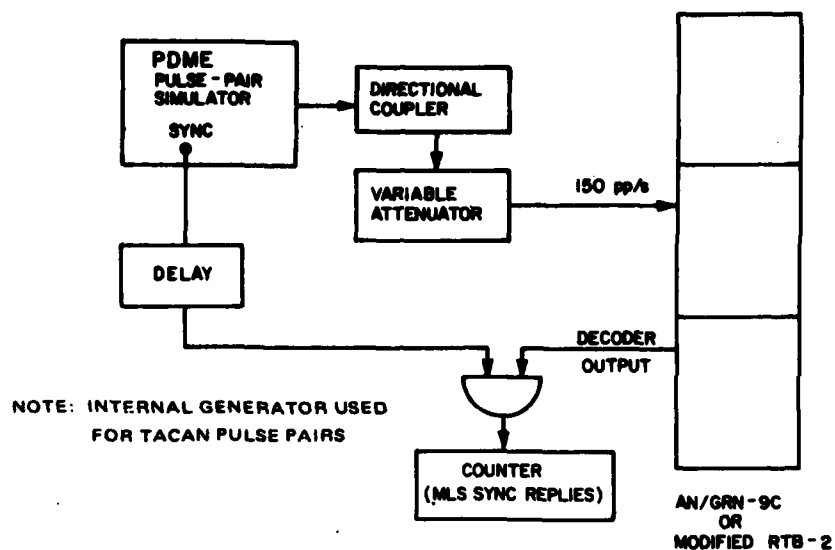


FIGURE 5. DECODER APERTURE MEASUREMENT CONFIGURATION, X-MODE.

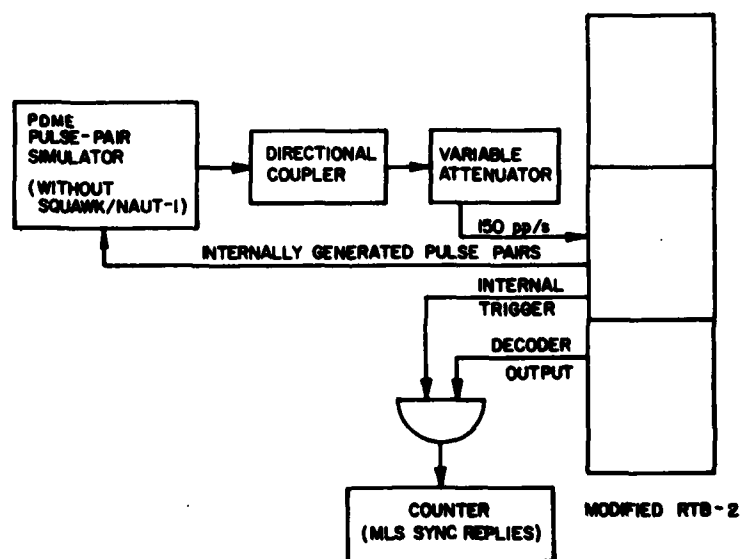


FIGURE 6. DECODER APERTURE MEASUREMENT CONFIGURATION, Y-MODE.

measurement, but the test signal pulse-pair spacing was varied from 30-42 μ s in one microsecond steps and set at 18 and 24 μ s.

Desired Signal Reply Efficiency Measurement

This test was performed for cochannel and adjacent-channel interference signals. Reply efficiency for X- and Y-mode operation was first measured without interference signals present and then with interference signals introduced at the receiver input.

Reply Efficiency (No Interference). FIGURE 7 shows the test configuration. The desired pulse pairs transmitted at 500, 1000, 2700, 3000 and 3300 pp/s entered the transponder receiver; the decoder output was gated with the input trigger. Coincidence of the trigger and decoder output permitted a counter to record the reply rate synchronous with the desired input rate. The input rate and the synchronous reply rate were recorded for desired signal levels of MDS and MDS +6 dB.

Reply Efficiency (With Interference). FIGURE 8 shows the test configuration for X-mode operation. The test proceeded as follows:

1. Transmit desired signal at 500 pp/s.
2. Transmit cochannel PDME pulse pairs at 150 Hz and power level of MDS -10 dB and use 12 μ s pulse-pair spacing.
3. Record the number of replies synchronous with the desired signal and the number of replies synchronous with the interfering signal.
4. Repeat steps 2 and 3 for PDME power levels of MDS to MDS + 40 dB in 10 dB increments.
5. Repeat steps 2, 3, and 4 for PDME PRF's of 500, 1000, 3000, and 5000 pp/s.
6. Repeat steps 2, 3, 4, and 5 for two more MLS pulse-pair spacings: one spacing corresponding to the edge of the decoder aperture (approximately 13 μ s) and one spacing corresponding to outside the aperture (18 μ s).

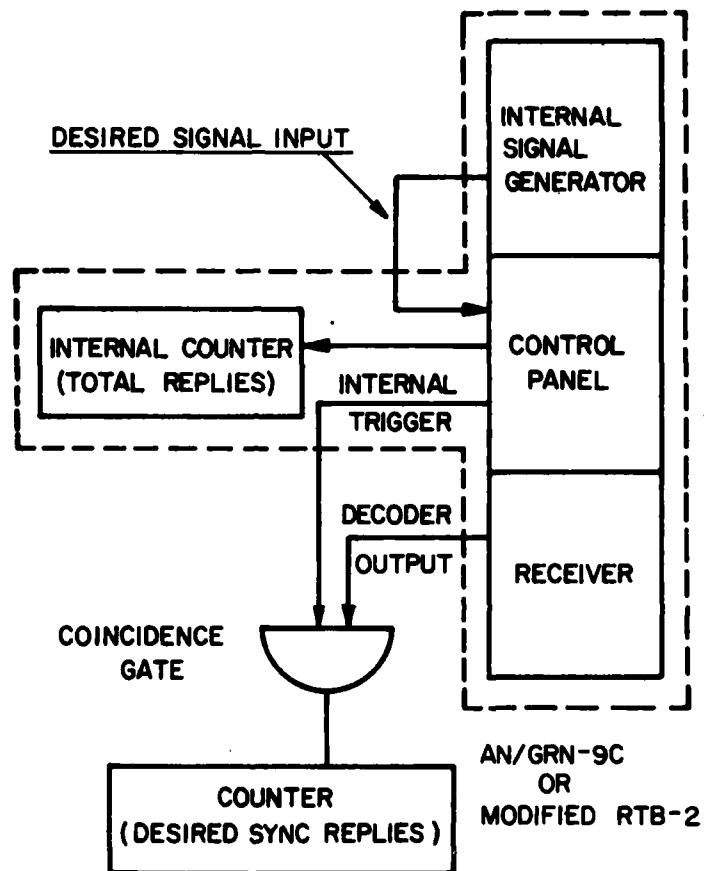
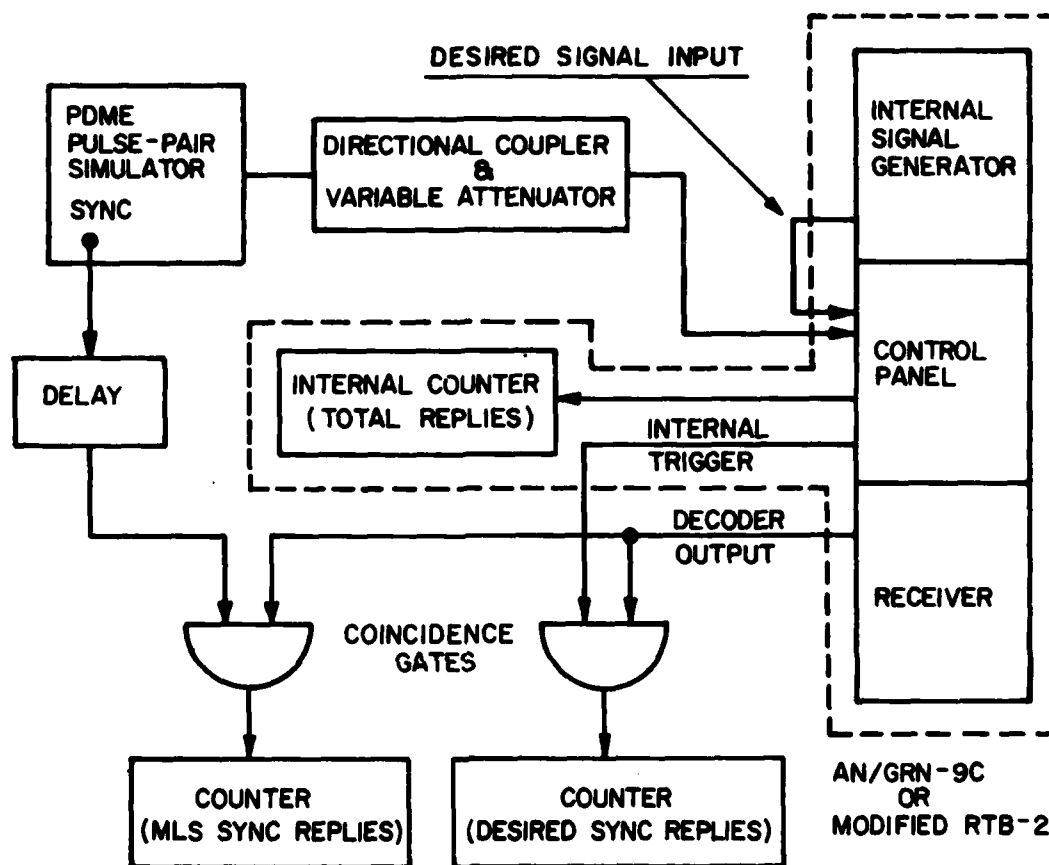


FIGURE 7. REPLY EFFICIENCY MEASUREMENT CONFIGURATIONS, DESIRED SIGNAL ONLY (NO PDME SIGNALS).



NOTE: DESIRED INTERROGATIONS GENERATED BY INTERNAL SOURCE AND PROVIDED TO RECEIVER AT RF INPUT.

FIGURE 8. REPLY EFFICIENCY MEASUREMENT CONFIGURATIONS, X-MODE WITH PDME SIGNALS.

FIGURE 9 shows the test configuration for the modified RTB-2 Y-mode reply efficiency tests. The test procedure was identical to the X-mode procedure except the PDME pulse-pair spacings were 36 μ s, approximately 37 μ s, and 42 μ s. The transponder internal generator was used as the interfering source while the SQUAWK/NAUT-I was used as the desired signal source.

The modified RTB-2 has a retriggerable blanking gate to suppress multipath signals generated from strong desired signals. The reply efficiency was measured as described above but with the blanking gate adjusted to lengths of 250 and 400 μ s. For the measurements, the threshold at which the gate was triggered was set at two levels, -70 and -80 dBm.

The adjacent-channel tests were performed similarly to the cochannel interference tests except the PDME rate was constrained to 3000 and 5000 pp/s; the pulse-pair spacings were 24 μ s, 36 μ s (Y-mode) and 12 μ s (X-mode); and frequency separation from the desired signal was ± 0.9 , ± 2 , ± 5 , and ± 10 MHz. The PDME power level was stepped from MDS to MDS + 50 dB in 5 dB increments. In some cases, additional measurements were made for ± 1.5 , ± 2.5 , ± 3 , and ± 4 MHz separations.

Deadtime Measurement

The AN/GRN-9C reduces the sensitivity of the receiver after the receipt of a pulse. The maximum change in sensitivity and the recovery time (echo suppression deadtime) depend on the strength of the received signal.

FIGURE 10 shows the test configuration for the measurement of the echo suppression deadtime. This test was performed for cochannel and adjacent-channel (± 0.9 , ± 2 , ± 5 , ± 10 MHz) pulses. The procedure was as follows:

1. Set cochannel PDME signal at 500 pp/s, 12 μ s pulse pairs, and signal level of MDS.

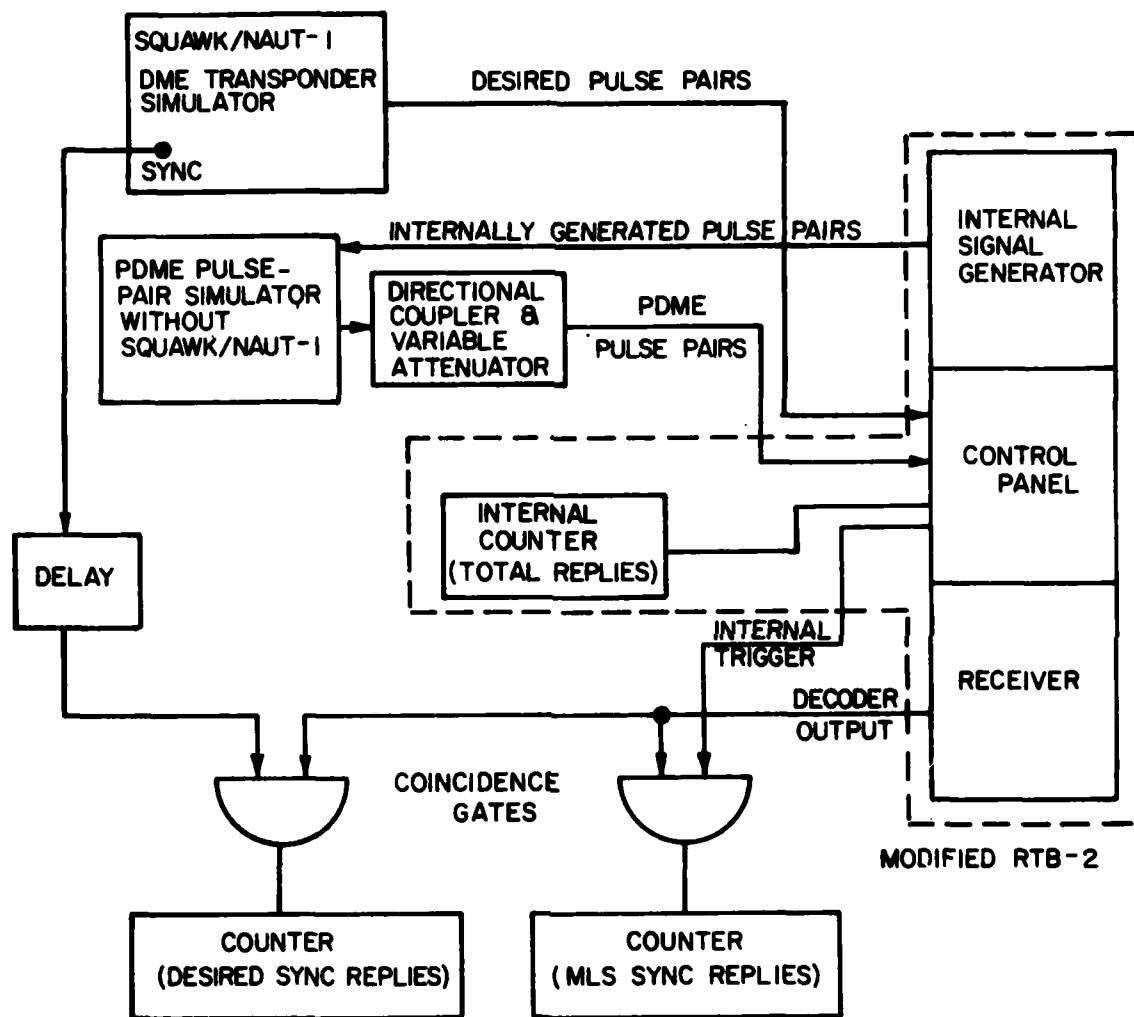
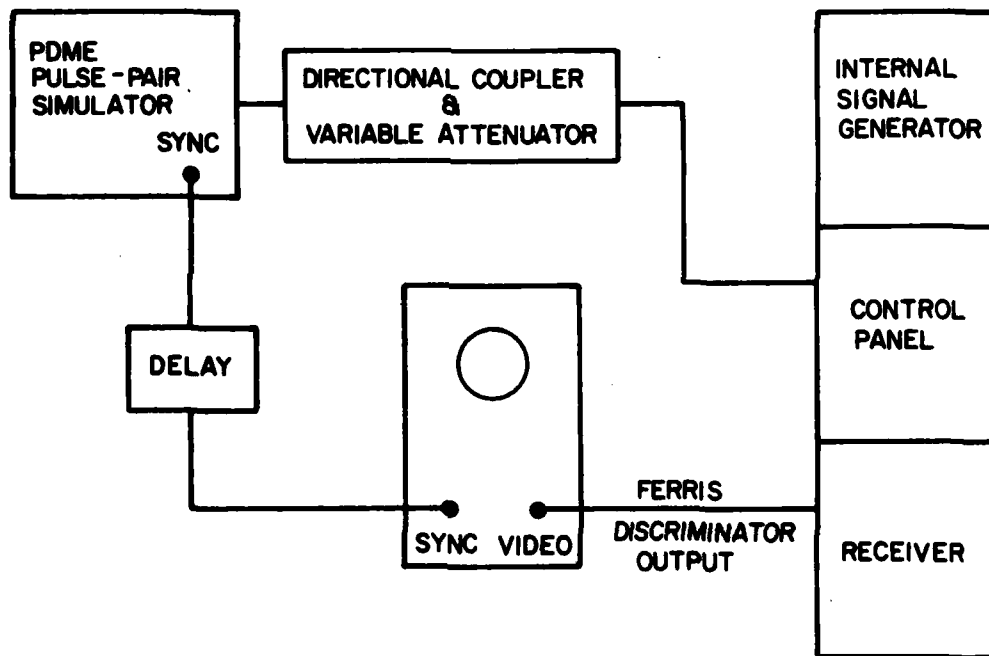


FIGURE 9. REPLY EFFICIENCY MEASUREMENT CONFIGURATIONS, Y-MODE WITH PDME SIGNALS.

2. Display the output of the Ferris discriminator on the oscilloscope. The output should be synchronous with the first pulse of the input PDME signal.
3. Record the length of time quieting occurs. This time will be measured from the first pulse to the end of quieting resulting from the second pulse.
4. Repeat step 2 for PDME signal levels from MDS + 5 dB to MDS + 45 dB in 5 dB steps.
5. Repeat steps 2 and 3 for pulse-pair spacings from 12-42 μ s.
6. Repeat steps 2, 3, and 5 for frequency separations of ± 0.9 , ± 2 , ± 5 , ± 10 MHz.



AN/GRN-9C

FIGURE 10. ECHO SUPPRESSION DEADTIME MEASUREMENT CONFIGURATION.

SECTION 3

ANALYSIS OF MEASURED DATA

The measured data obtained by NAFEC for the twelve interrogators and two transponders are examined in this section. The data are used to develop preliminary susceptibility characteristics for TACAN/DME's that operate in the presence of interference caused by PDME signals.

INTERROGATOR DATA

Measured data that show the susceptibility of TACAN and DME interrogators to PDME interference were obtained for three TACAN's and nine DME's. These data were examined by considering the TACAN performance separately from the DME performance. The measured results for the three TACAN's were compared and a composite TACAN susceptibility envelope was developed. A similar envelope was developed for the DME's. Both envelopes were compared and a TACAN/DME interrogator susceptibility envelope was developed.

The measurement results for each interrogator are included in APPENDIXES A-I and L-N. Each appendix includes the measured data as described in TABLE 4. FIGURES 11-17 are sample plots of this data for an RCA AVQ-70, DME interrogator.

FIGURES 11 and 12 show the RCA AVQ-70, X-mode decoder aperture determined by using TACAN/DME pulse pairs and PDME pulse pairs, respectively. Comparison of FIGURES 11 and 12 shows the same decoder aperture width, but the aperture obtained with PDME pulse pairs is shifted approximately 1 μ s to the right relative to the decoder aperture derived with TACAN/DME pulse pairs. This shift, which can also be noted in the data for other equipments, may result because of the method used to create the PDME pulse pair.

In FIGURE 2, the output of the SQUAWK/NAUT-I simulator is TACAN/DME pulse pairs having peak-to-peak spacing equaling leading-edge-to-leading edge spacing.

TABLE 4
INTERROGATOR DATA

Measurement	Type of Data
Decoder Aperture (X- and Y-mode)	<ol style="list-style-type: none">1. Decodes vs pulse-pair spacing for TACAN/DME signals @ MDS, MDS + 10 dB, MDS + 20 dB.2. Decodes vs pulse-pair spacing for PDME signals @ MDS, MDS + 10 dB, MDS + 20 dB.
Acquire-Lock (X- and Y-mode)	<ol style="list-style-type: none">1. Maximum PDME signal level permitting range or azimuth acquisition vs PDME PRF with PDME pulse-pair spacing as a parameter (cochannel).2. Maximum PDME signal level permitting range or azimuth acquisition vs desired signal level with PDME pulse-pair spacing and PRF as parameters (cochannel).3. Maximum PDME signal level permitting range or azimuth acquisition vs Δf with PDME pulse-pair spacing and PRF as parameters (adjacent-channel).

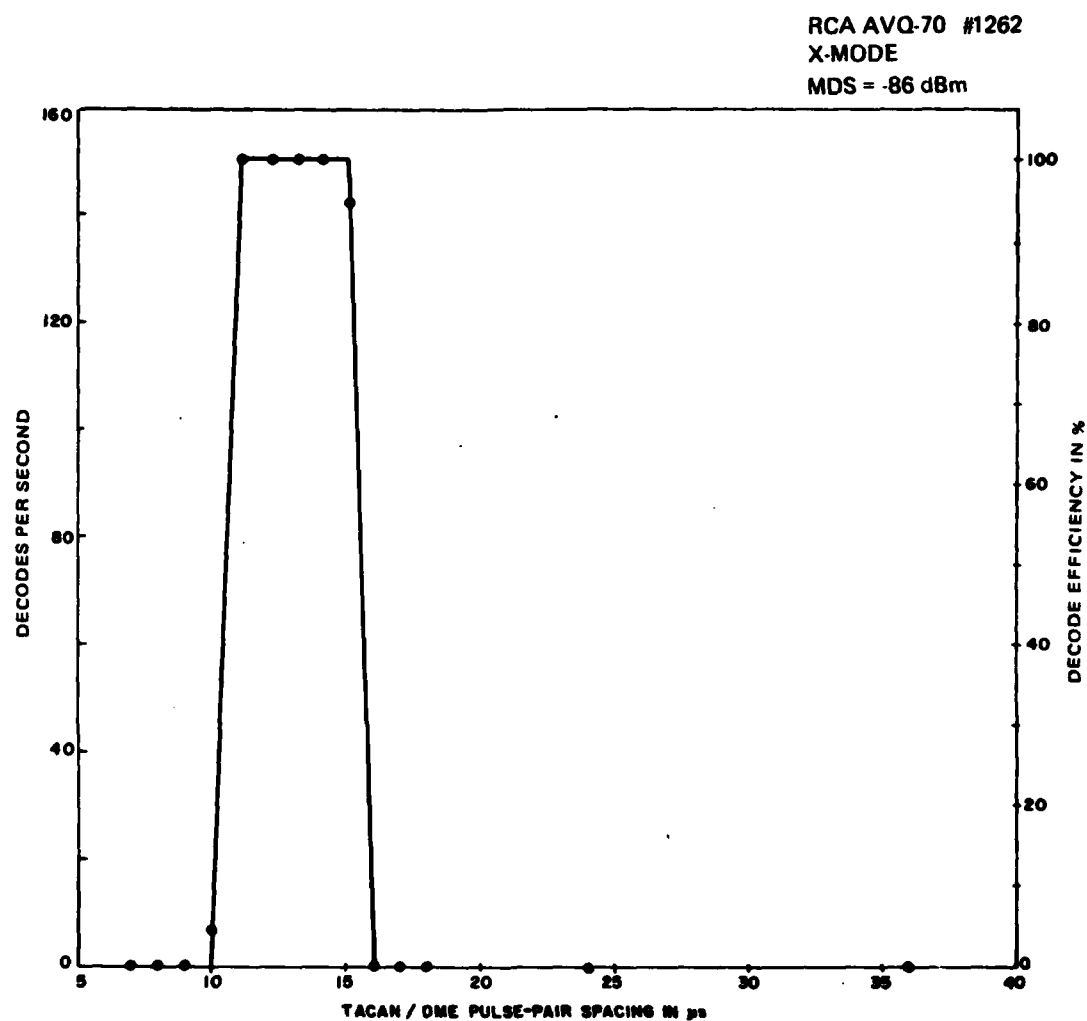


FIGURE 11. RCA AVQ-70 DECODER APERTURE USING TACAN PULSE PAIRS (MDS + 20 dB).

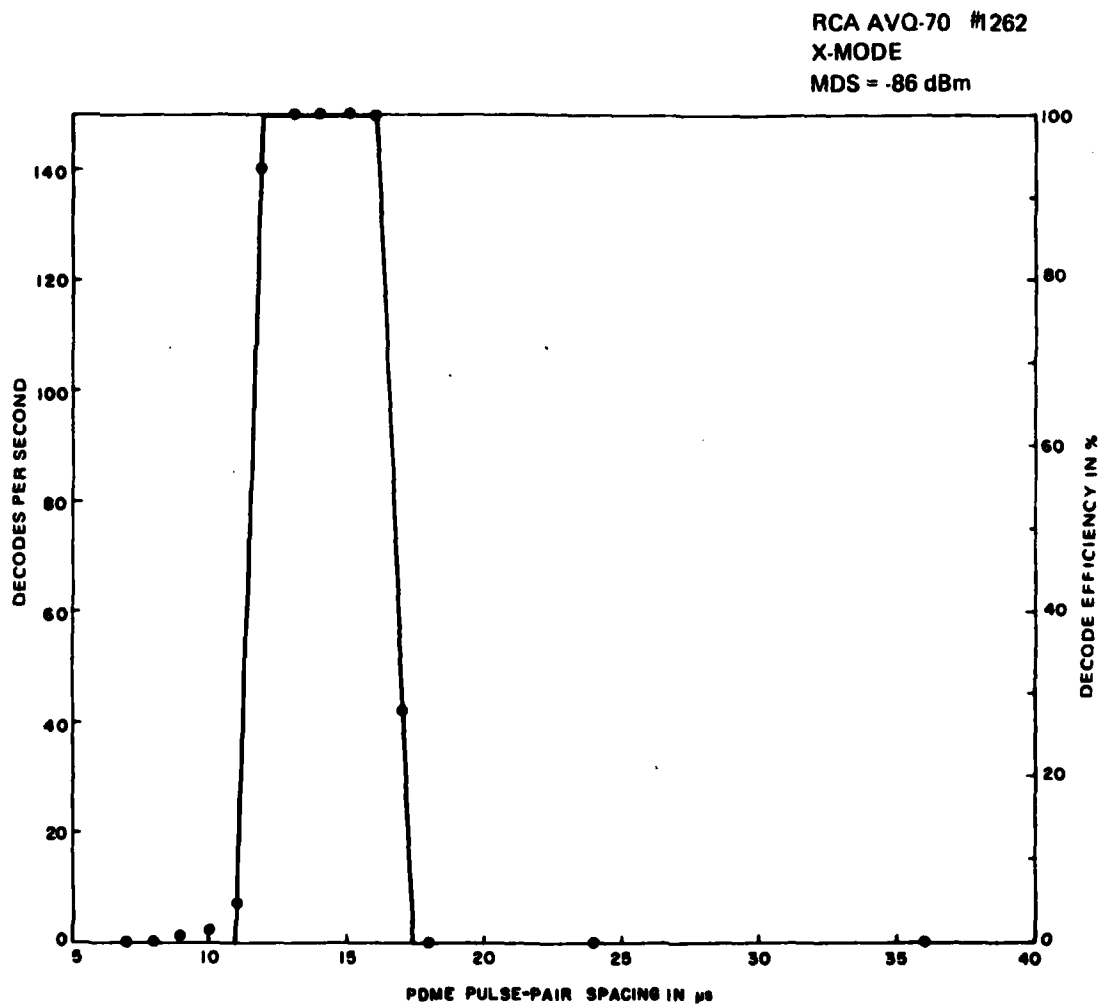


FIGURE 12. RCA AVQ-70 DECODER APERTURE USING PDME PULSE PAIRS (MDS + 20 dB).

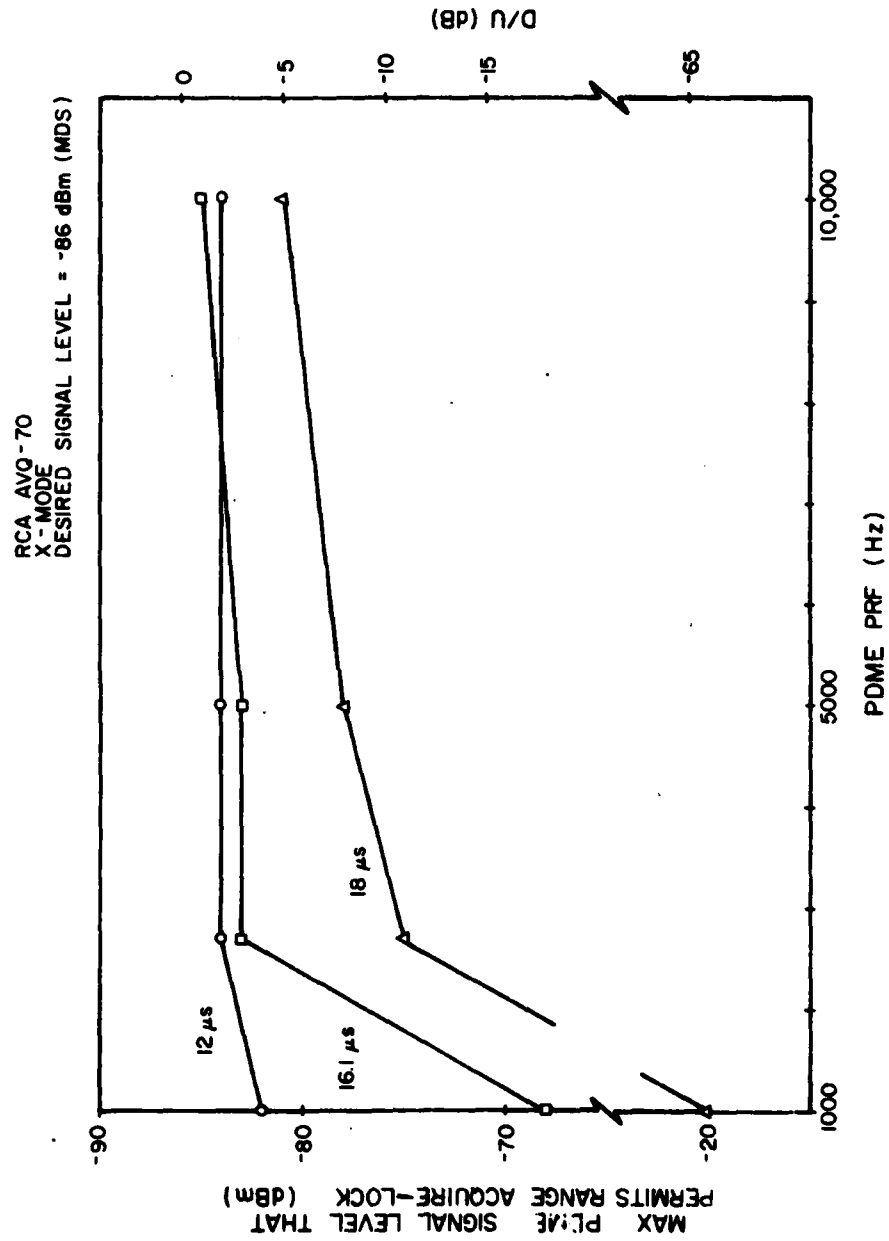


FIGURE 13. RCA AVQ-70 SUSCEPTIBILITY TO PDME SIGNALS.

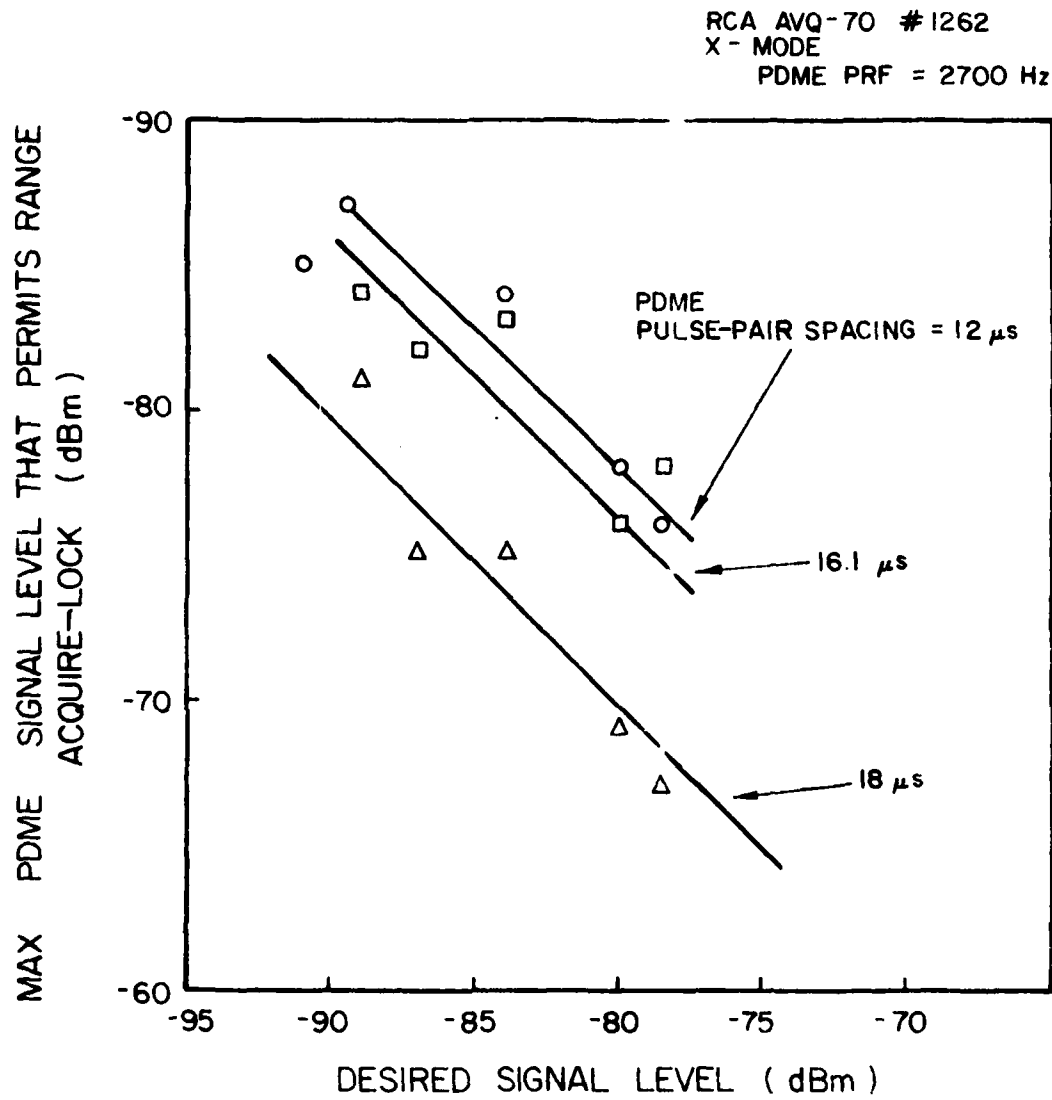


FIGURE 14. RCA AVQ-70 SUSCEPTIBILITY TO PDME SIGNALS AT 2700 pp/s AS A FUNCTION OF DESIRED SIGNAL LEVELS.

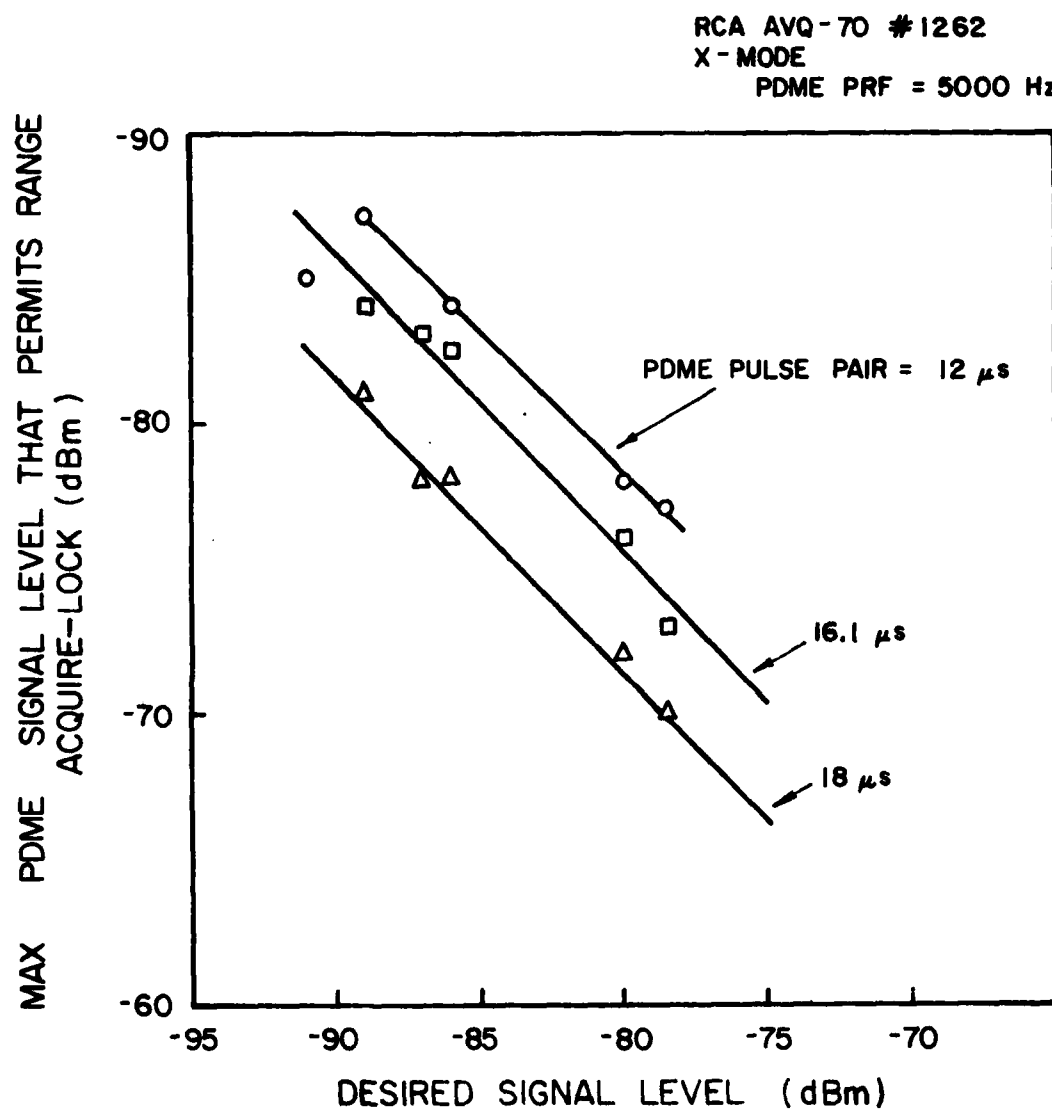


FIGURE 15. RCA AVQ-70 SUSCEPTIBILITY TO PDME SIGNALS AT 5000 pp/s AS A FUNCTION OF DESIRED SIGNAL LEVELS.

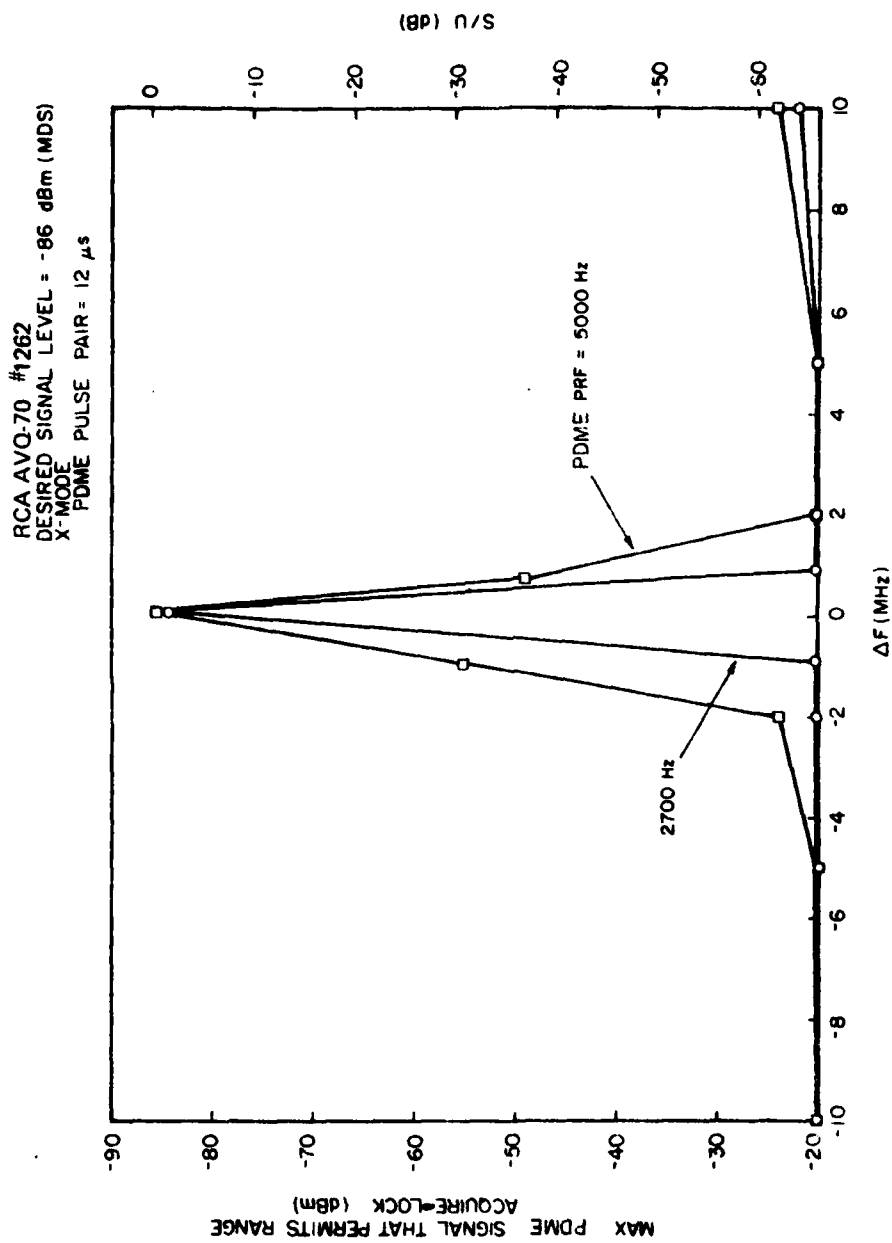


FIGURE 16. RCA AVQ-70 ADJACENT-CHANNEL SUSCEPTIBILITY TO PDME, 12- μ s PULSE PAIRS.

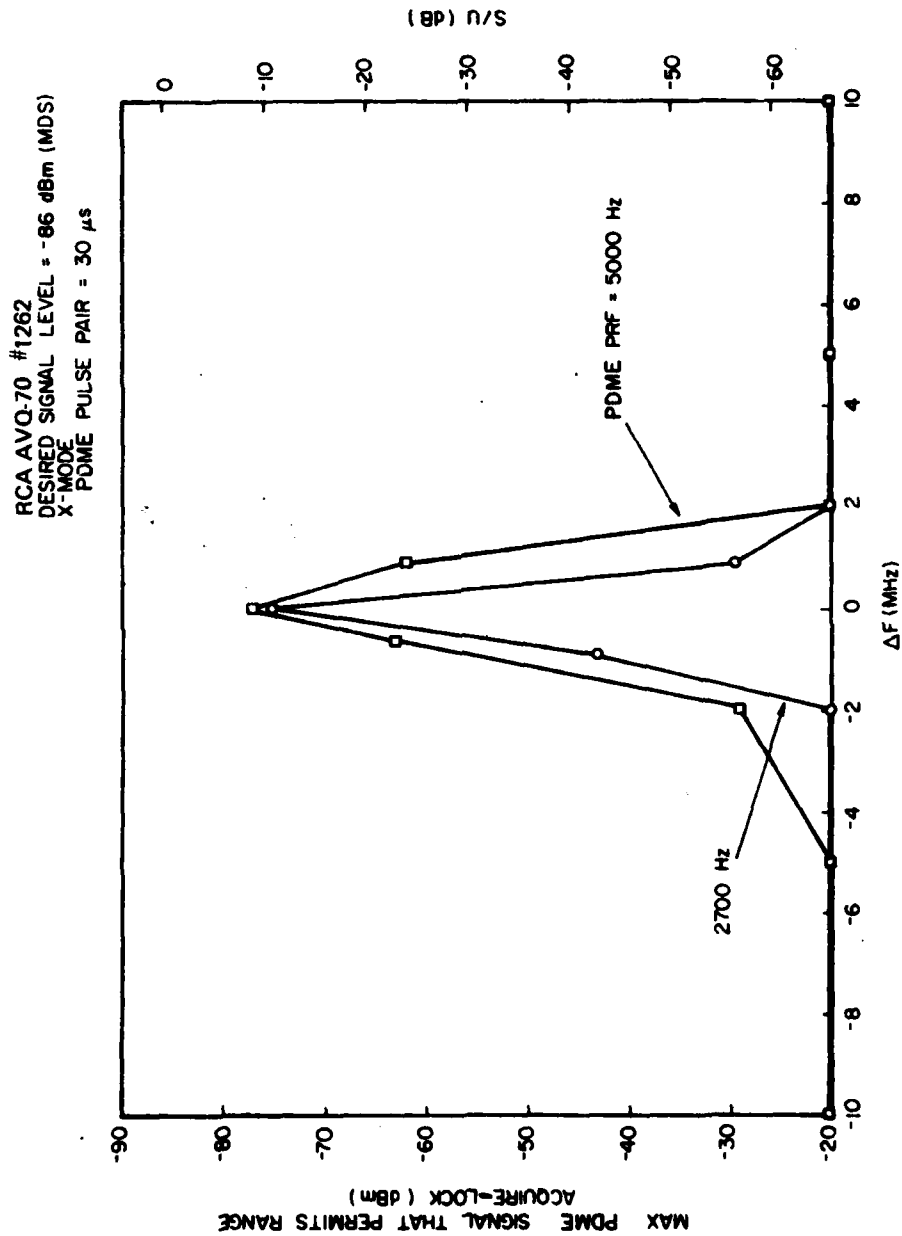


FIGURE 17. RCA AVQ-70 ADJACENT-CHANNEL SUSCEPTIBILITY TO PDME, 30- μ s PULSE PAIRS.

To form PDME pulse pairs, the first pulse of each SQUAWK/NAUT-I pulse pair is modified to give a sharper leading edge. Thus the PDME pulse pairs have peak-to-peak spacing slightly larger than leading-edge-to-leading-edge spacing. This points out a need to define MLS PDME pulse spacing as being either peak-to-peak or leading-edge-to-leading-edge.

The interrogator decoder senses the pulse pair spacing by a leading-edge-to-leading-edge measurement. In FIGURE 18, the PDME and TACAN/DME pulse pairs are superimposed so that the peak-to-peak spacings are the same. The figure also indicates the leading edge of each first pulse (by an arbitrary amplitude level) and the companion leading-edge-to-leading-edge spacing. Note that this spacing for the PDME pulse pair is shorter than for the TACAN/DME pulse pair. Thus, for a given peak-to-peak spacing the decoder aperture measured with PDME pulses will lag the aperture derived with TACAN/DME (two identical pulses) by the difference in the leading-edges of the first pulses. This difference is a function of the measurement procedure and if the PDME pulse-pair spacing was initially adjusted based on leading-edge-to-leading-edge spacing or the interrogator measured leading-edge-to-leading-edge at the half-amplitude level, the apertures of FIGURES 11 and 12 would be identical.

In FIGURE 13, the plot illustrates the susceptibility of the RCA AVQ-70 to PDME signals. Susceptibility is measured in terms of the largest interfering signal that will permit range (or azimuth) acquisition. Several combinations of PDME pulse-pair rate and spacing are considered in the figure. When the PDME pulse-pair spacing changed from a 12 μ s decodable signal to an 18 μ s nondecodable signal, the interrogator susceptibility decreased by no more than 66 dB. However, as the interference pulse-pair rate increased, the decrease in susceptibility gained by using nondecoding pulse pairs was lost. At high interference rates (10,000 pp/s), the susceptibility of the interrogator to decodable and nondecodable^a interference differed by only 3 dB.

^aThe use of "nondecodable" to describe interference in this report, refers to the use of an interfering signal with a pulse-pair spacing which would be expected to be rejected by the decoder within the victim receiver. However, as realized during the conduct of the NAFEC tests, many of the receivers did in fact decode these "nondecodable" signals

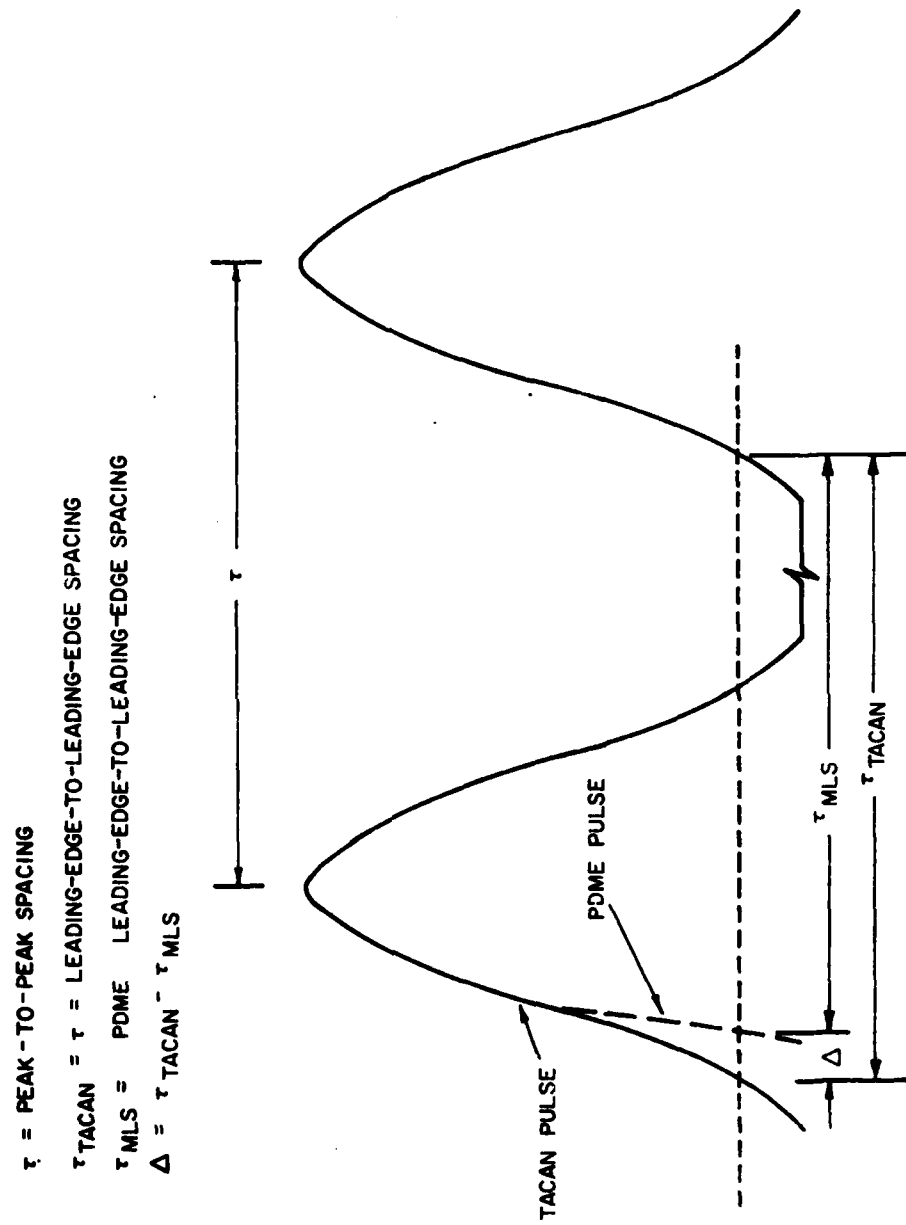


FIGURE 18. TACAN/DME TO PDME PULSE-PAIR SPACING COMPARISON.

FIGURES 14 and 15 show plots of the RCA AVQ-70 interrogator interference susceptibility as a function of desired signal level with PDME pulse-pair spacing and PRF as parameters. These plots indicate a linear relationship between susceptibility and desired signal. Since these plots are approximately parallel, the plots of FIGURE 13 will retain the same relationship to one another regardless of the desired signal level. The data in FIGURES 14 and 15 give validity to the conclusion that the data in FIGURE 13 plotted with respect to the minimum desired-to-undesired signal ratio (D/U) that permits range (or azimuth) acquisition suffices to describe interrogator susceptibility to the PDME signals.

Examining data in the appendixes for other equipments leads to the same conclusion regarding the plots of susceptibility with respect to minimum D/U that permits range or azimuth lock.

FIGURES 16 and 17 show interrogator susceptibility as a function of frequency separation of desired and undesired signals, PDME PRF, and PDME pulse-pair spacing. These plots also can be assumed to be invariant with respect to specific desired and undesired signal level. A plot of minimum D/U that permits range or azimuth lock will suffice to describe the interrogator susceptibility to PDME signals.

TACAN Interrogators

A TACAN interrogator provides a pilot with range and bearing information to a specific ground or airborne transponder. Interference could affect both the bearing and range deriving functions of the interrogator. The data in APPENDIXES A, B, and C for the AN/ARN-21C, AN/ARN-52(V), and AN/ARN-84 show that the bearing or azimuth function is more susceptible to the PDME interference than the ranging function. A measure of the susceptibility of an interrogator to PDME signals is the minimum D/U ratio that permits it to acquire azimuthal information in the presence of cochannel or adjacent-channel interference. The desired and undesired signal levels required to determine these ratios are given on the data sheets.

The susceptibility of the three TACAN's tested is shown in FIGURES 19-22. FIGURES 19 and 20 represent susceptibility in the presence of decodable and nondecodable cochannel PDME signals, respectively. Susceptibility in the presence of decodable and nondecodable adjacent-channel PDME signals is shown in FIGURES 21 and 22. TABLE 5 shows the measured decoder apertures using PDME pulse pairs.

Cochannel Susceptibility. FIGURE 19 shows that the AN/ARN-52 exhibited the least susceptibility to the decodable cochannel interference while the AN/ARN-21C appeared the most susceptible of the three equipments. A D/U = +7 dB is the smallest ratio permitting all equipments to acquire azimuth (and range) information in the presence of decodable PDME signals having PRF's up to and including 10,000 pp/s. For PDME signal rates that do not exceed 2700 pp/s, a D/U = +5 dB permits all three equipments to acquire azimuth information.

A TACAN or DME interrogator must acquire range or azimuth information in the presence of a cochannel interfering TACAN transponder signal that is 8 dB below the desired signal level (D/U = +8 dB).^{10,11} This criterion applies only for an interfering TACAN/DME signal rate of 2700-3600 pp/s. As seen in FIGURE 19, this criterion is satisfied using PDME signals at rates that do not exceed 10,000 pp/s. Thus, the TACAN interrogator susceptibility to decodable, cochannel PDME signals satisfies the cochannel susceptibility requirements for decodable, cochannel TACAN signals.

With PDME signals consisting of nondecodable pulse pairs (pulse-pair spacing not within the decoder aperture) and transmitted at a rate less than 5000 pp/s, the susceptibility to the interference (plotted in FIGURE 20) as compared to FIGURE 19 decreased for the AN/ARN-21C and AN/ARN-52(V). However,

¹⁰FAA-AC-00-31, U.S. National Aviation Standard for the VORTAC System, 10 June 1970.

¹¹Radio Technical Commission for Aeronautics, *Minimum Performance Standards-Airborne Distance Measuring Equipment (DME) Operating Within the Radio-Frequency Range of 960-1215 MHz*, Document No. 151, Washington, DC, 18 August 1972.

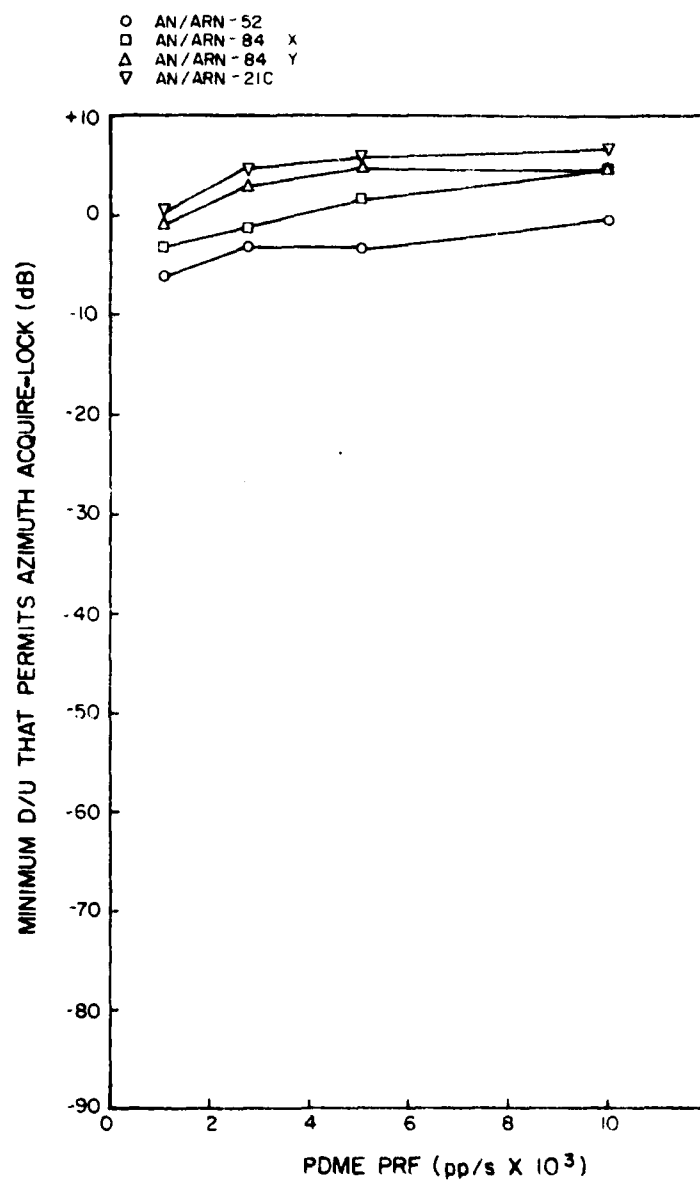


FIGURE 19. TACAN INTERROGATOR PERFORMANCE IN PRESENCE OF PDME COCHANNEL INTERFERENCE (INSIDE DECODER APERTURE).

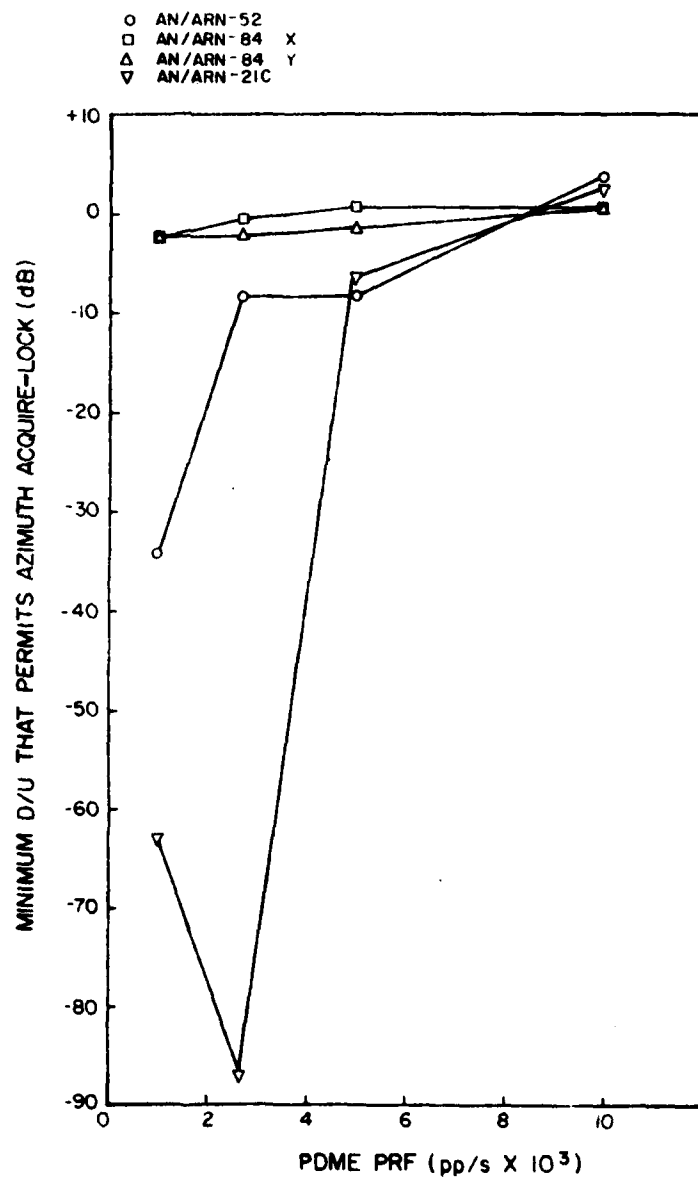


FIGURE 20. TACAN PERFORMANCE IN PRESENCE OF PDME COCHANNEL INTERFERENCE (OUTSIDE DECODER APERTURE).

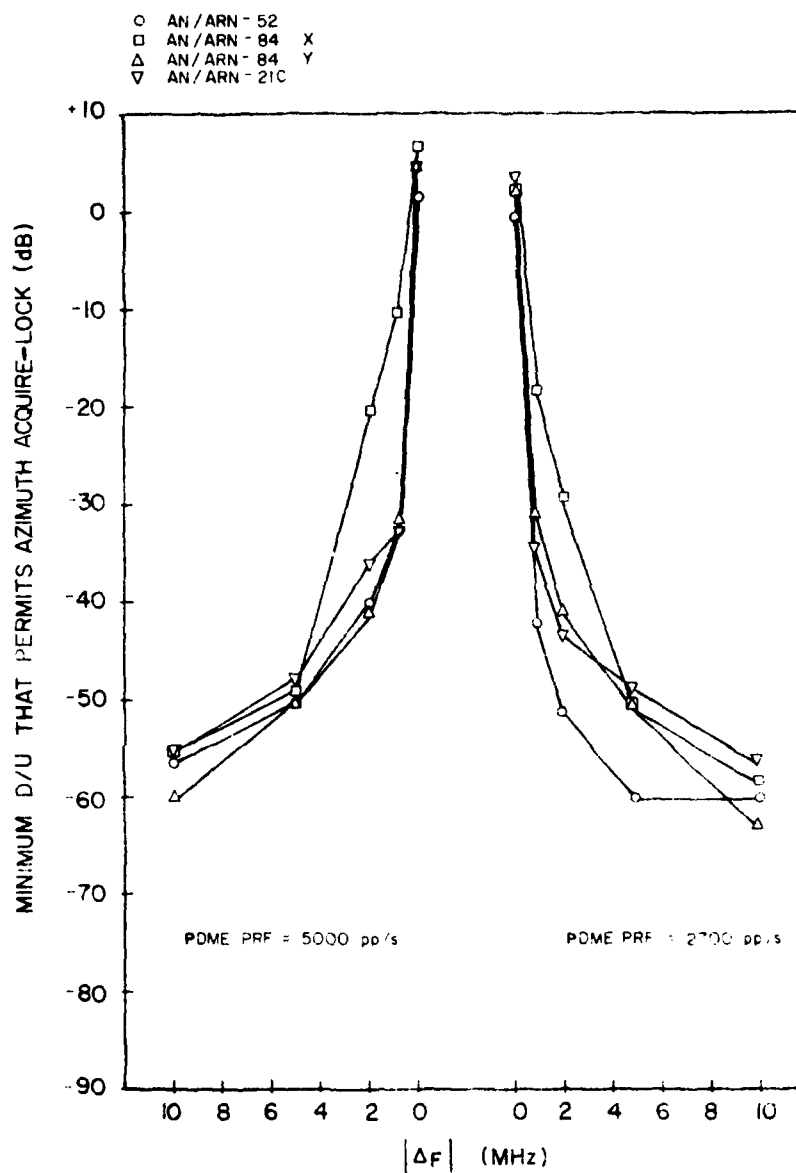


FIGURE 21. COMPOSITE TACAN INTERROGATOR PERFORMANCE IN PRESENCE OF PDME ADJACENT-CHANNEL INTERFERENCE (INSIDE DECODER APERTURE).

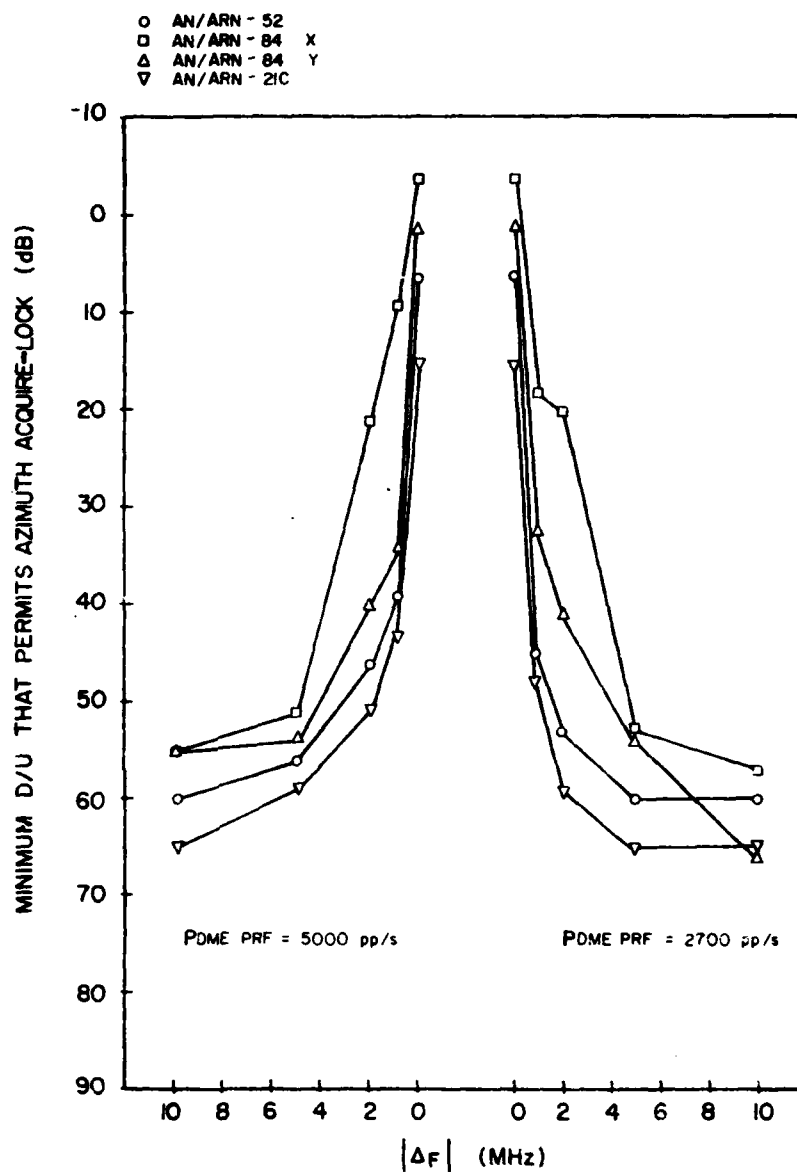


FIGURE 22. COMPOSITE TACAN INTERROGATOR PERFORMANCE IN PRESENCE OF PDME ADJACENT-CHANNEL INTERFERENCE (OUTSIDE DECODER APERTURE).

the nondecodability of the PDME pulse pairs did not significantly affect the AN/ARN-84 because its susceptibility remained relatively unchanged as shown by comparing FIGURES 19 and 20. A D/U = +4 dB would be the smallest ratio permitting these equipments to acquire azimuth (and range) information in the presence of nondecodable PDME signals having rates that do not exceed 10,000 pp/s. For PDME signal rates less than or equal to 2700 pp/s, the minimum D/U that permits acquisition of azimuth information for the three equipments tested is 0 dB. Comparison of the D/U for the two PDME rates with the TACAN cochannel criterion of +8 dB shows a 4-8 dB margin for TACAN interrogators acquiring range information in the presence of non-synchronous PDME signals. However, it should be noted that in an actual operational environment, a cochannel undesired source may be providing synchronous replies to a victim TACAN interrogator. This situation was not covered in this test program, but it is expected that the protection criteria would be the same as presently required for TACAN to TACAN frequency assignments (8 dB).

TABLE 5
TACAN DECODER APERTURE

Nomenclature	Aperture Width (μ s) ^a
AN/ARN-21C ^b	< 7 - > 18
AN/ARN-52	8.5 - 16.4
AN/ARN-84 (X-mode)	9.2 - 15.4
AN/ARN-84 (Y-mode)	26.6 - 32.6

^aBased on decoding 75 of 150 pp/s with a signal level of MDS + 10 dB.

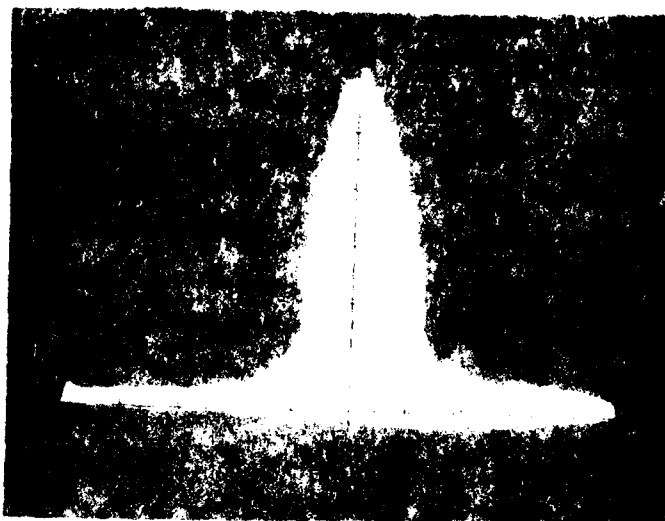
^bFull aperture could not be measured because of test equipment limitations.

Adjacent-Channel Susceptibility. FIGURES 21 and 22 show the susceptibility of the TACAN equipments to PDME signals that are not cochannel with the desired signal. A cursory inspection of the plots indicates that the two older equipments are less susceptible to the interference than the AN/ARN-84.

References 10 and 11 require that an interrogator be capable of acquiring range or azimuth information with $D/U = -42$ dB when the desired and undesired signal have the same pulse-pair spacing and are separated by 1 MHz, and with $D/U = -50$ dB when the separation is 2 MHz or more. As with the cochannel criterion, these adjacent-channel criteria apply only for a decodable interfering TACAN signal that has a rate of 2700-3600 pp/s. In FIGURE 21, the AN/ARN-52(V) is the only equipment that satisfies these criteria when the interference rate is 2700 pp/s. None of these TACAN's tested acquired data with $D/U = -42$ dB or $D/U = -50$ dB when the interference rate was 5000 pp/s. A $D/U \geq -10$ dB for a first adjacent-channel situation and $D/U \geq -20$ dB for a second adjacent-channel situation would permit each equipment tested to acquire azimuth and range data for decodable PDME signals transmitted at rates less than or equal to 5000 pp/s. For decodable PDME signals at rates that do not exceed 2700 pp/s, the minimum D/U ratios that would permit all three interrogators to acquire azimuth information in the presence of first- and second-adjacent-channel PDME signal interference are -18 and -29 dB, respectively.

Even for a PDME PRF of 2700 pp/s, the data show that some TACAN interrogators will not acquire azimuth information in accordance with the requirements of References 10 and 11. One reason for this may be that the spectral fall off for the PDME pulse pair is slower than that of a normal TACAN/DME pulse pair. FIGURES 23 and 24 show the power spectra of both signals and by comparison the PDME signal is approximately 28 dB down from the fundamental at 1 MHz while the TACAN signal is 40 dB down. This 12 dB difference may partially explain why the TACAN interrogators did not acquire azimuth information with $D/U = -42$ dB with a 1 MHz separation of desired and undesired signals.

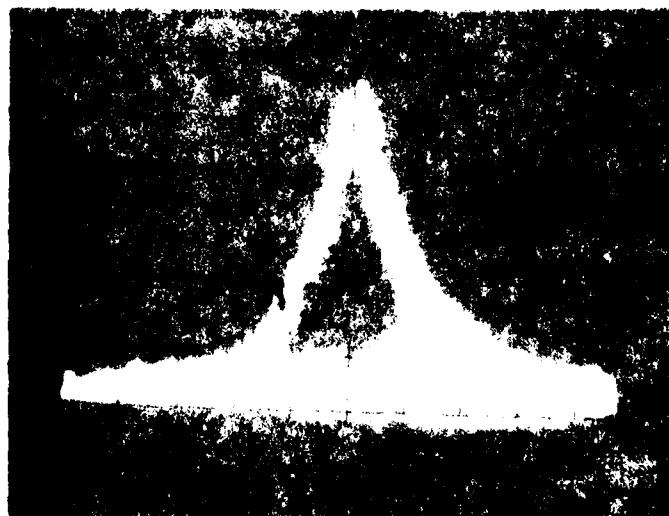
For nondecodable PDME signals at 2700 pp/s, only the AN/ARN-21C and the AN/ARN-52 acquired azimuth data for $D/U \leq -42$ dB (1 MHz) and ≤ -50 dB (2 MHz) (FIGURE 22). The AN/ARN-21C was the only equipment to meet the criteria for the 5000 pp/s PDME PRF. A $D/U \geq -9$ dB first-adjacent-channel situation and $D/U \geq -21$ dB second-adjacent-channel situation would permit each equipment



Vert: 10 dB/div

Horiz: 1 MHz/div

FIGURE 15. SPECTRUM OF POWER SUPPLY FILTER
OUTPUT (CH 2)



Vert: 10 dB/div

Horiz: 1 MHz/div

FIGURE 16. SPECTRUM OF FILTERS 1 AND 2 FOR
ADDITIONAL EVALUATION

tested to acquire azimuth or range data for PDME signal rates less than or equal to 5000 pp/s. For nondecodable PDME signals at rates not exceeding 2700 pp/s, the D/U ratios that would permit all three interrogators to acquire azimuth information in the presence of first- and second-adjacent-channel PDME signal interference are -18 and -20 dB, respectively.

The adjacent-channel results, like the cochannel results for the TACAN's tested, show that the AN/ARN-84 (the most susceptible of the three interrogators to the interference) susceptibility to PDME signals appears essentially invariant with respect to changes in PDME pulse-pair spacing. The minimum D/U that would permit the AN/ARN-84 to acquire azimuth data in the presence of PDME signals is less than that required by Reference 10 for azimuth acquisition in the presence of TACAN/DME signals. This implies that first- and second-adjacent-channel PDME-to-TACAN interference protection criteria may be more stringent than -42 and -50 dB.

Decoder Aperture. TABLE 5 lists the measured decoder apertures for the three TACAN's. The aperture of the AN/ARN-21C was the widest; 18 and 42 μ s (pulse-pair spacings considered for XZ and YZ channels) would be considered outside the apertures of the AN/ARN-52 and AN/ARN-84 but not that of the AN/ARN-21C.

Interpretation of Measured Results for TACAN's. The data presented for the three TACAN interrogators show that the older equipments [AN/ARN-21C and AN/ARN-52(V)] have a lesser susceptibility to the PDME interference than the newer TACAN's represented by the AN/ARN-84. The AN/ARN-52(V) and AN/ARN-21C will soon be replaced in the inventory by the AN/ARN-118. The AN/ARN-118 and the AN/ARN-84 will be the two major TACAN nomenclatures in the military inventory. Therefore, the performance of the AN/ARN-84 in the presence of PDME signals will be representative of TACAN interrogators operating when the PDME becomes an operational subsystem of the MLS. The channel assignment criteria for PDME channels must provide the protection that will permit an AN/ARN-84 to

obtain bearing information from a TACAN/DME or VORTAC-DME transponder in the presence of PDME signals.

Presently, a TACAN or DME transponder gets an operating frequency based on satisfying the cochannel criterion of $D/U = +8$ dB, first-adjacent-channel criterion of $D/U = -42$ dB, and second-adjacent-channel criteria of $D/U = -50$ dB at an interrogator receiver anywhere in the TACAN service volume. Therefore, these criteria guarantee the integrity of the transponder service volume so that signals from another TACAN ground station will not affect the service of this one ground station. To operate a PDME transponder requires a channel/frequency assignment such that it will not interfere with or degrade the operation of existing services. Proponents of MLS L-Band PDME assume little care is required in assigning channels to PDME transponders as long as the modes of operation (i.e., the pulse-pair spacings) are different from those of the existing services. However, the test data in FIGURES 19-22 indicate differently even for the case where MLS PDME would use X- or Y-mode channels.

Assume an X-mode channel will be assigned to a PDME transponder. Using the worst-case measurement results for decodable PDME signals at 2700 pp/s, the minimum D/U permitting a PDME transponder to operate cochannel, first-adjacent-channel, and second-adjacent-channel with X-mode TACAN interrogators are +5, -18, and -29 dB, respectively. As already noted these are more stringent requirements, except for cochannel, than the +8, -42, and -50 dB criteria employed to guarantee TACAN/DME operation in the presence of TACAN/DME signal from other stations. Thus, a PDME X-mode channel assignment may be more difficult to obtain than a TACAN X-mode channel assignment.

Now assume an XZ or YZ channel will be assigned to a PDME transponder. This time, using the worst-case results for nondecodable PDME signals at 2700 pp/s, the D/U values that will protect X- or Y-mode TACAN systems operating cofrequency, first-adjacent-channel, and second-adjacent-channel with the PDME transponder are 0, -18, and -20 dB, respectively. In comparison with existing TACAN-to-TACAN protection requirements, these requirements are more stringent

except for the cochannel situation. Except for cofrequency situations, this implies more difficulty in assigning XZ and YZ channels than normal X- or Y-mode TACAN channels. The difficulty would increase with increasing PDME signal rate.

The above discussion may leave the reader with the impression that the TACAN interrogators tested could operate satisfactorily under the existing TACAN-to-TACAN interference protection criteria regarding interfering TACAN/DME pulse pairs. However, no TACAN-to-TACAN tests were performed to make this determination and it is quite possible that these particular equipments would perform similarly with PDME or TACAN/DME interfering signals.

DME Interrogators

FIGURES 25-32 show the ability of DME interrogators to acquire range lock in the presence of PDME signals. The first four figures represent results with cochannel PDME signals and the last four figures represent results when the PDME signals are separated in frequency from the desired signal (adjacent-channel). TABLE 6 lists the measured decoder apertures for each DME interrogator.

Cochannel. FIGURES 25 and 26 show that the susceptibility of the DME's to decodable interfering pulse pairs varies slightly with increasing interference pulse-pair rate. Comparison of these results with the TACAN susceptibility in FIGURE 19, shows that, on the average, the DME interrogator is approximately 5 dB more tolerant of the interference than the azimuth function of the TACAN interrogator.

With nondecodable PDME signals, the DME interrogator susceptibility to the PDME signal, as shown in FIGURES 27 and 28, generally remains low for low interfering rates but increases with increasing PDME PRF for newer equipments. Older DME interrogators' (e.g., NARCO UDI 4 and KING KN 60C) susceptibility is relatively invariant from low interfering rates to high interfering rates. Of

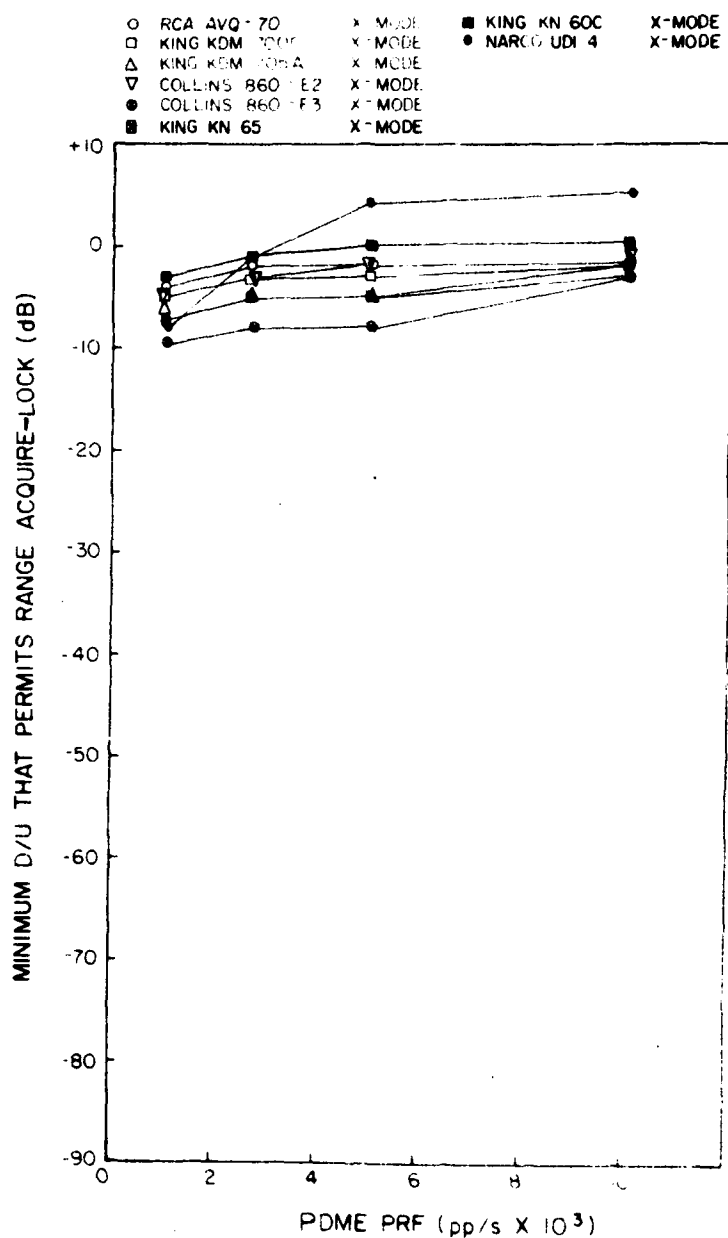


FIGURE 25. DME INTERROGATOR PERFORMANCE IN PRESENCE OF PDME COCHANNEL INTERFERENCE (INSIDE DECODER APERTURE), X-MODE.

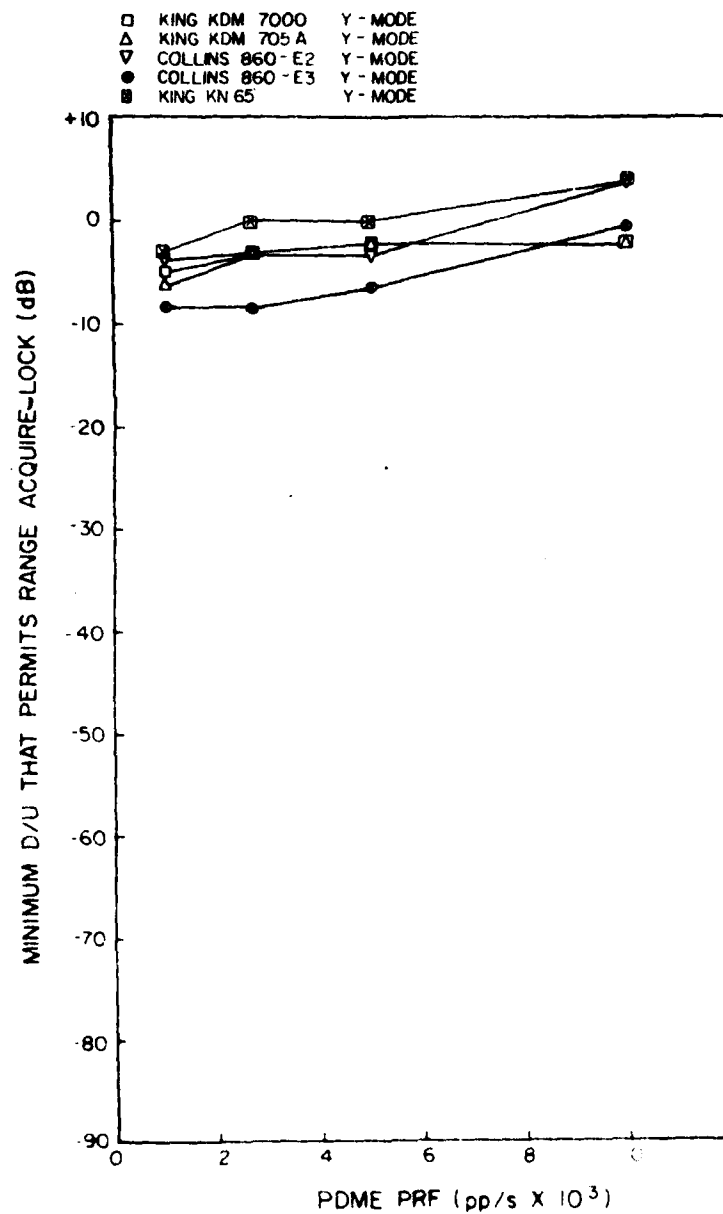


FIGURE 26. DME INTERROGATOR PERFORMANCE IN PRESENCE OF PDME COCHANNEL INTERFERENCE (INSIDE DECODER APERTURE), Y-MODE.

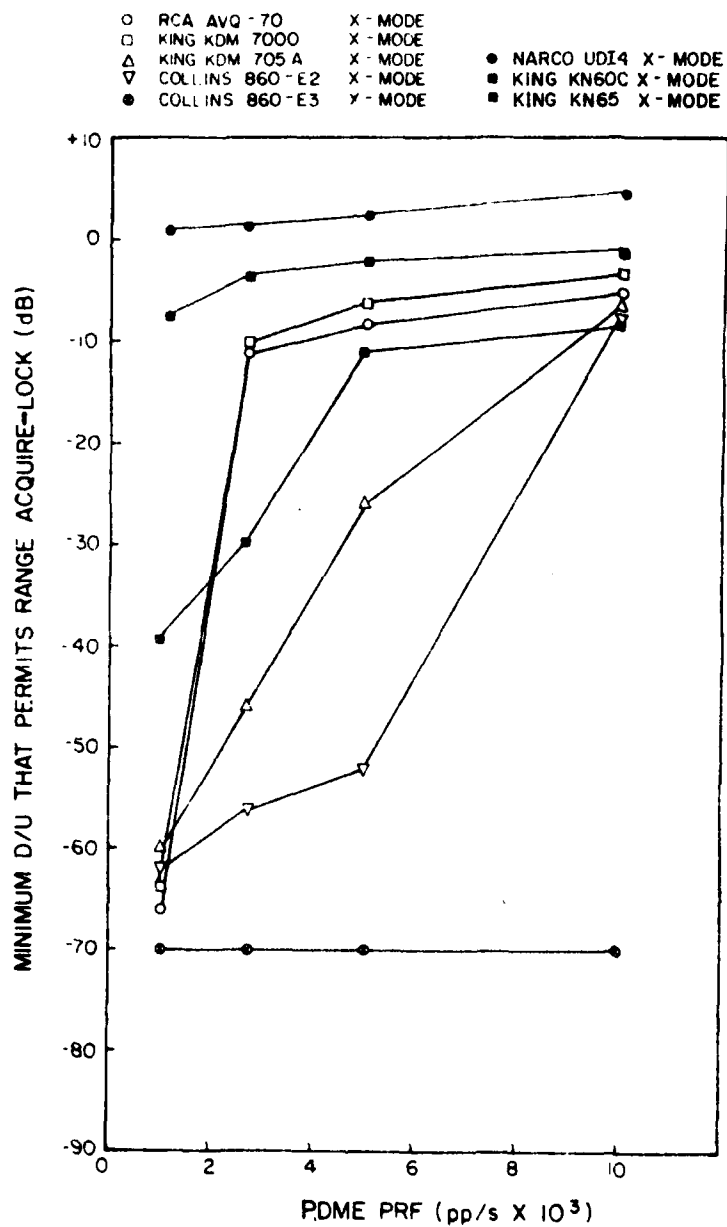


FIGURE 27. DME INTERROGATOR PERFORMANCE IN PRESENCE OF PDME COCHANNEL INTERFERENCE (OUTSIDE DECODER APERTURE), X-MODE.

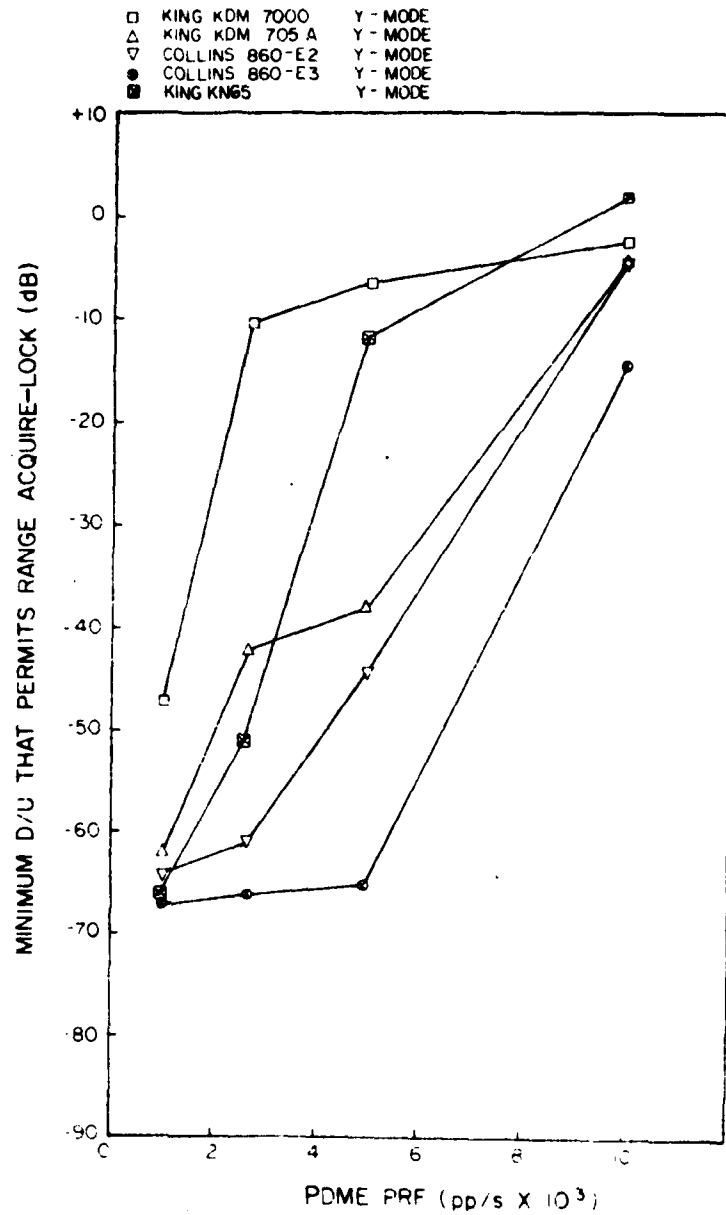


FIGURE 28. DME INTERROGATOR PERFORMANCE IN PRESENCE OF PDME COCHANNEL INTERFERENCE (OUTSIDE DECODER APERTURE), Y-MODE.

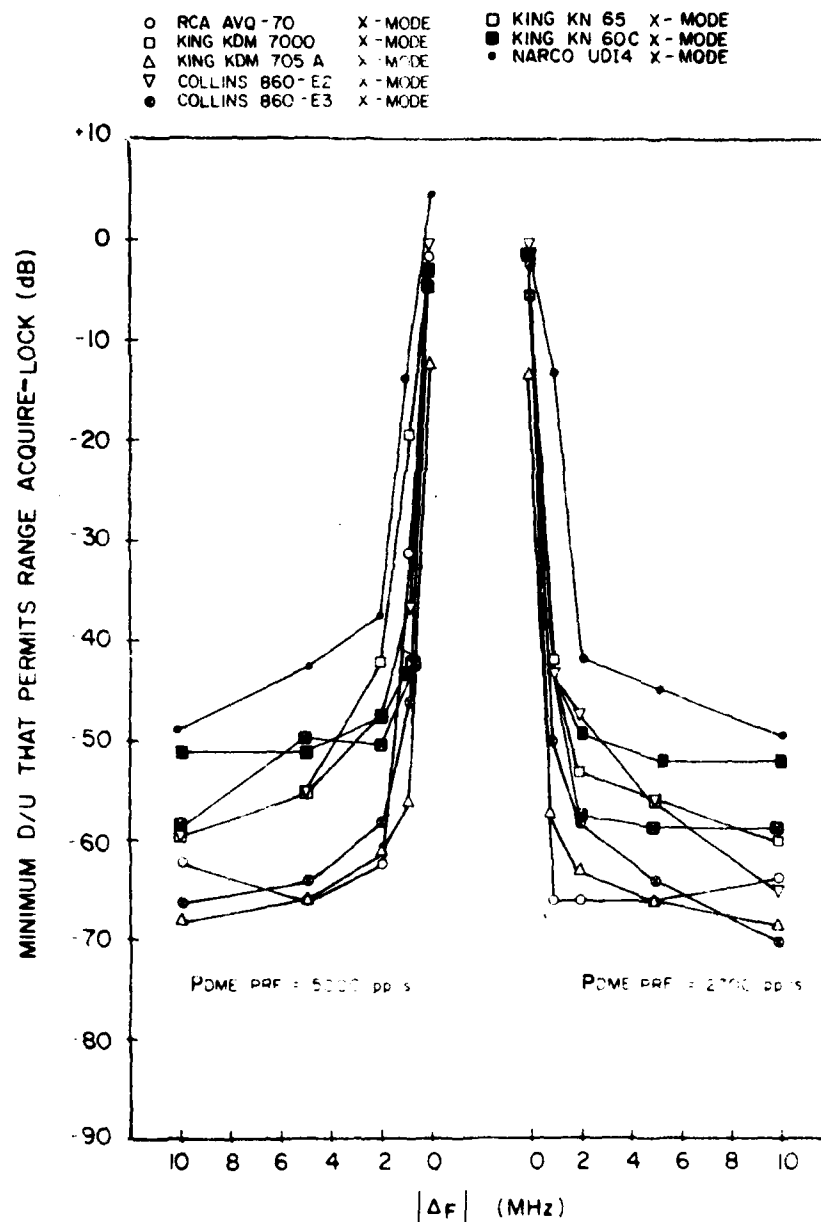


FIGURE 29. COMPOSITE DME INTERROGATOR PERFORMANCE IN PRESENCE OF PDME ADJACENT-CHANNEL INTERFERENCE (INSIDE DECODER APERTURE), X-MODE.

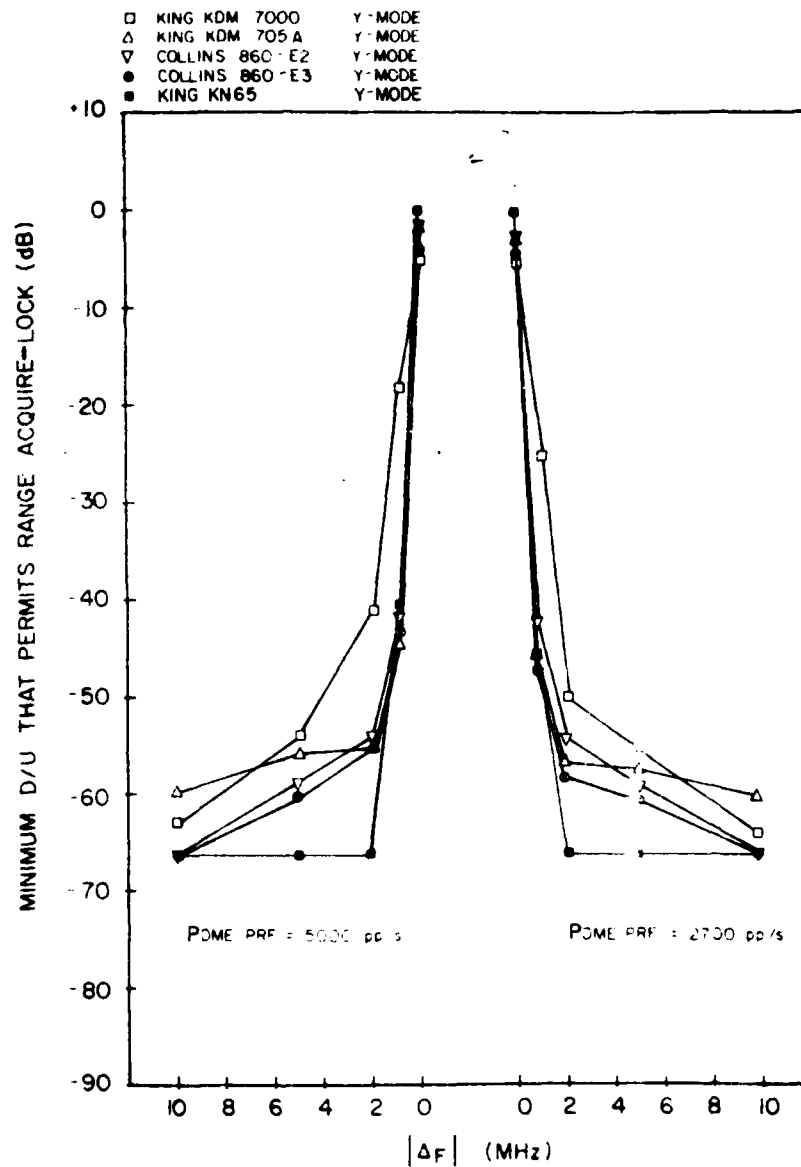


FIGURE 30. COMPOSITE DME INTERROGATOR PERFORMANCE IN PRESENCE OF PDME ADJACENT-CHANNEL INTERFERENCE (INSIDE DECODER APERTURE), Y-MODE.

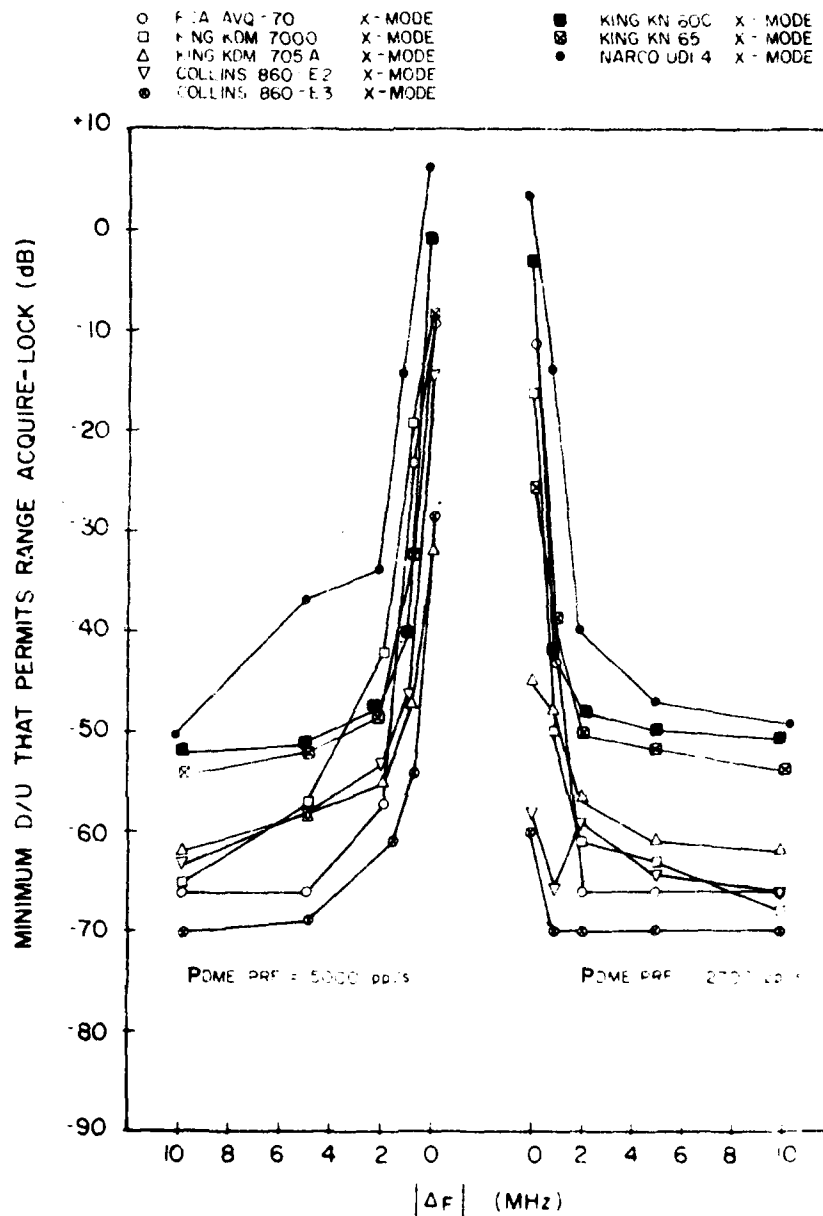


FIGURE 31. COMPOSITE DME INTERROGATOR PERFORMANCE IN PRESENCE OF PDME ADJACENT-CHANNEL INTERFERENCE (OUTSIDE DECODER APERTURE), X-MODE.

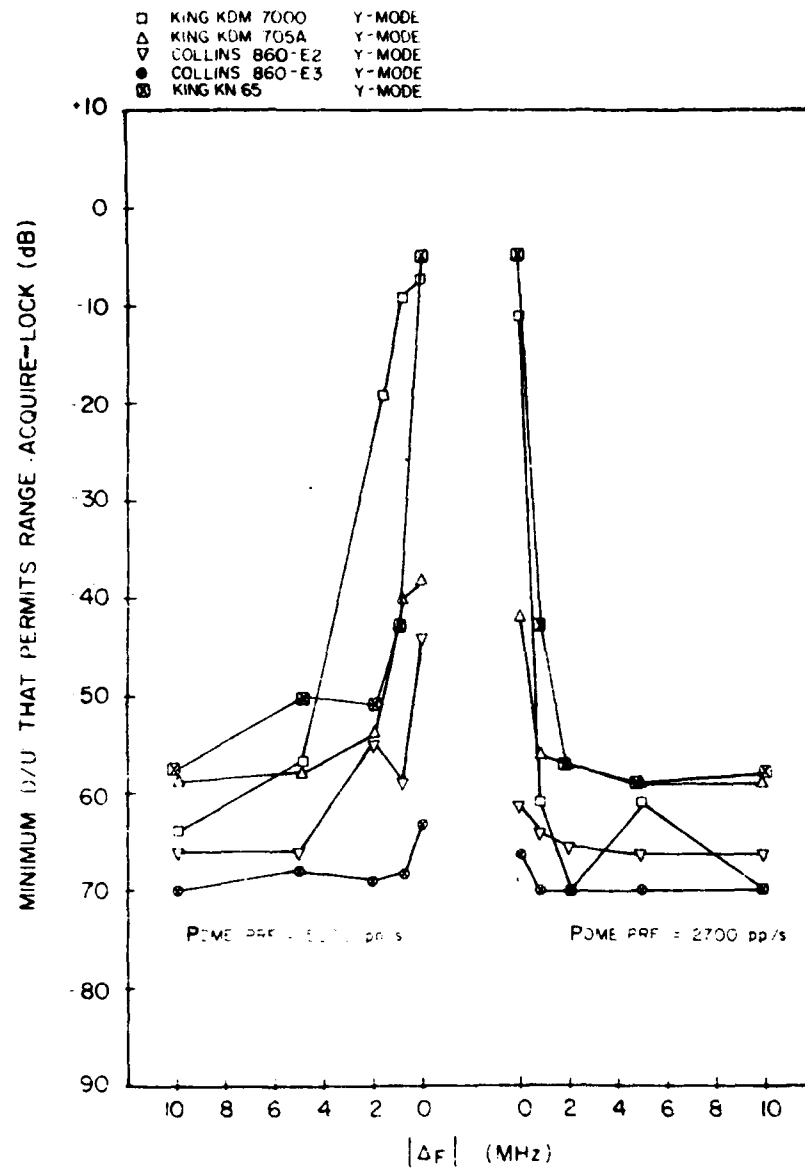


FIGURE 32. COMPOSITE INTERROGATOR PERFORMANCE IN PRESENCE OF PDME ADJACENT-CHANNEL INTERFERENCE (OUTSIDE DECODER APERTURE), Y-MODE.

the older interrogators tested, the NARCO UDI 4 appears to be the most susceptible to nondecodable PDME signals. Of the newer interrogators, the KING KDM 7000 appears the most susceptible and the COLLINS 860-E3 the least susceptible to nondecodable PDME signals. However, the KING KDM 7000 is tolerant of low PRF (<1000 pp/s) nondecodable interference.

TABLE 6
DME INTERROGATOR DECODER APERTURE^a

Nomenclature	X-Mode Aperture (μ s)	Y-Mode Aperture (μ s)
COLLINS 860-E2	8.5-15.1	28.5-34.0
COLLINS 860-E3	10.5-14.4	27.6-32.5
KING KDM 705A	8.8-14.5	27.4-31.5
KING KDM 7000	9.2-14.6	26.5-34.6
KING KN 60C	8.6-16.2	---
KING KN 65	8.4-13.8	26.6-31.9
RCA AVQ-70	11.2-16.2	---

^aThe decoder apertures of the NARCO DME 190 and the NARCO UDI 4 were not measured.

Comparison of the results of nondecodable interference for TACAN and DME performance (FIGURES 20, 25 and 26) shows approximately a 0 to 5 dB differential in TACAN azimuth and DME range acquisition performance at high interference pulse-pair rates. In the presence of either decodable or nondecodable pulse-pairs at higher rates, the KING 60C, the KING KDM 7000 and the AN/ARN-84 appeared invariant to interference PRF or pulse-pair spacing.

The D/U ratio that permitted range acquisition by all the tested DME equipments was +5 dB for cochannel decodable and nondecodable interference. This value applies for PDME signal rates that do not exceed 10,000 pp/s. In order to protect all the tested DME equipments from decodable and nondecodable PDME interference at a PRF of 2700 pp/s, D/U values of 0 and +1 dB are required. However, if only those newer DME equipments are to be protected (eliminate UDI 4 and KN 60C), these D/U values required for protection at 2700 pp/s drop to -2

and -10 dB for decodable and nondecodable interference respectively. Comparing these values to the TACAN/DME cochannel D/U criterion of +8 dB shows a 7 to 18 dB margin for DME interrogators acquiring range information in the presence of PDME signals. This implies that the D/U criterion to be employed for PDME-to-TACAN cochannel interference protection may be a value 7 to 18 dB less than the TACAN-to-TACAN criterion. The actual value used would depend upon whether the PDME interference is decodable or nondecodable and whether the object is to extend protection to all DME interrogators or only those representative of the future environment.

Adjacent-Channel. FIGURES 29-32 show the DME interrogator susceptibility to decodable and nondecodable PDME interfering signals. If the interrogator equipment is able to acquire range lock with $D/U \leq -42$ dB at a 1 MHz frequency separation and a $D/U \leq -50$ dB for separation of 2 MHz or greater, then the DME interrogator performance in the presence of PDME signals will be in accordance with the U.S. National Standard (Reference 10) requirements performance in the presence of decodable TACAN/DME signals.

For decodable interference, five of the eight equipments tested operating in X-mode (FIGURE 29) met the adjacent-channel requirements for an interfering PDME PRF of 2700 pp/s; the NARCO UDI 4 did not meet either the first- or the second-adjacent-channel requirements and the COLLINS 860-E2 and KING KN 60C did not meet the second-adjacent-channel requirements. With an interfering PDME PRF of 5000 pp/s, the NARCO UDI 4, the KING KDM 7000, the KING KN 60C, the COLLINS 860-E2 and the RCA AVQ-70 did not comply with the requirements. For X-mode performance of these equipments (FIGURE 30), the KING KDM 7000 did not meet the requirements regardless of the PDME pulse-pair rate.

The minimum D/U's that permit the DME interrogators to acquire range information in the presence of first- and second-adjacent channel decodable PDME signals at 2700 pp/s, are -12 and -42 dB, respectively. For a PDME PRF of 5000 pp/s, the ratios are -14 and -38 dB.

FIGURES 31 and 32 show the equipment response in the presence of non-decodable pulse pairs. For X-mode operation (FIGURE 31), the NARCO UDI 4 and the KING KN 65 did not acquire range data for $D/U \leq -42$ dB at ± 1 MHz separation and the NARCO UDI 4 and the KING KN 60C did not acquire range data for $D/U \leq -50$ dB at ± 2 MHz separation for an interfering MLS-DME rate of 2700 pp/s. For an interfering PDME rate of 5000 pp/s, neither the NARCO UDI 4, the KING KDM 7000, the KING KN 60C nor the KING KN 65 met first- or second-adjacent channel requirements while operating in the X-mode. All Y-mode equipments satisfied the above conditions for 2700 pp/s (FIGURE 32), but the KING KDM 7000 was the only equipment not meeting the conditions for the 5000 pp/s interference rate.

The D/U ratios that would permit the DME interrogators to acquire range information in the presence of first- and second-adjacent channel nondecodable PDME signals at 2700 pp/s are -16 and -40 dB. For a PDME PRF of 5000 pp/s the ratios are -10 and -23 dB.

Decoder Aperture. TABLE 6 shows the measured decoder apertures for seven of the nine DME's tested. These apertures are sufficiently narrow so that pulse-pair spacings of 18 and 42 μ s should not be decoded.

Interpretation of Measured Results for DME's. The measured results show that of the DME interrogators tested, the NARCO UDI 4, the KING KN 60C and the KING KDM 7000 rank first, second and third regarding susceptibility to PDME signal interference. While the first two equipments are considered relatively old and not representative of future DME interrogators, the KING KDM 7000 has been purchased in quantity by foreign and domestic airlines for use on wide-body and supersonic aircraft. It should remain in their inventories for several years. Therefore, the assignment of PDME channels must account for the susceptibility of the NARCO UDI 4 if the objective is to extend protection to all DME interrogators. However if only those interrogators that are representative of the future environment are to be protected, then the assignment must account for the susceptibility of the KING KDM 7000 to interference from PDME signals.

As with TACAN equipments, DME's are sufficiently susceptible to the interfering PDME signals so that D/U values needed for cochannel, first-adjacent-channel, and second-adjacent-channel protection for the DME are comparable or more stringent than the TACAN-to-TACAN protection criteria. For decodable PDME signals at 2700 pp/s, the D/U values needed to protect all of the DME interrogators tested would be 0, -12, and -42 dB for cochannel and adjacent-channel situations. Increasing the rate to 5000 pp/s changes the permissible D/U's to -4, -12, and -38 dB.

With nondecodable PDME signals at 2700 pp/s, the minimum permissible D/U's would be +1, -16, and -40 dB. A MLS signal rate of 5000 pp/s increases the cochannel, first-adjacent-channel, and second-adjacent-channel minimum permissible D/U's to +2, -10, and -23 dB.

Attempting PDME channel assignments on existing X- or Y-mode channels or proposed XZ- or YZ-mode channels will be as difficult or more difficult than trying to assign TACAN/DME channels. The conditions needed to assure DME operation in the presence of MLS DME become more difficult to obtain as the interfering PDME PRF increases

The above discussion may indicate that the tested DME interrogators could operate satisfactorily under the existing TACAN-to-TACAN interference protection criteria regarding interfering TACAN/DME pulse pairs. However no TACAN/DME-to-DME tests were performed to make this determination and it is quite possible that these equipments would perform similarly with PDME or TACAN/DME interfering signals.

NARCO DME 190

The majority of TACAN/DME interrogators employ a search and tracking loop that allows the interrogator to be more resistant to interference after acquiring lock than in the search mode. An interrogator will maintain range and azimuth lock unless signal parameters change significantly.

However, the NARCO DME 190 does not employ a tracking loop, but acquires and displays range information based on the output of a correlator. If the correlator output occurs for a particular range, the range is displayed. If a correlator output then occurs for another range, the new range is immediately displayed, but the displayed range can change without new signal parameters (received power or pulse width). It cannot be assumed that once the NARCO DME 190 has displayed range it will continue to do so like other interrogators. Therefore, one way to measure NARCO DME 190 susceptibility to interference is to determine the average or expected time to display range data. The time to display range data was recorded 25 times for each set of desired and undesired signal conditions, and the mean and standard deviation were calculated (APPENDIX I). It was assumed that the interrogator became susceptible to interference when the time to display range exceeded one standard deviation of the expected time to display range with no interference. This was the assumed, arbitrary boundary on acceptable DME 190 performance in the presence of interference.¹² This boundary will be referred to as λ .

The NARCO DME 190 was susceptible to interfering PDME signals. In the presence of decodable, cochannel, PDME signals, the DME 190 would display range in λ seconds when the PDME signal level did not exceed -82 dBm and the PDME PRF was either 2700 or 5000 pp/s. This result was observed for desired signal levels of -85 dBm (MDS - 3 dB) to -76 dBm (MDS + 6 dBm). Thus, it appeared the interrogator would display range in λ seconds for D/U = 8 dB (the existing TACAN/DME cochannel siting criterion) in the presence of PDME signals.

The DME 190 performance improved when the interference was nondecodable, cochannel PDME signals. The interference susceptibility criterion and the PDME signal level at which the expected time to display the range exceeded λ seconds are given in TABLE 7. The susceptibility increased with increasing PDME PRF. The D/U at which the X-mode interrogator became susceptible to the interference

¹²Patrick, J. and Craig, D., *JTIDS 960 to 1215 MHz Radio Navigation Band Compatibility Test Results*, FAA-RD-75-194, ECAC, Annapolis, MD, October 1975.

TABLE 7

NARCO DME 190 SUSCEPTIBILITY TO COCHANNEL,
NONDECODABLE, PDME SIGNALS

X-Mode, PDME Pulse-Pair Spacing = 18 μ s

PDME PRF (pp/s)	Desired Signal Level (dBm)	PDME Signal Level ^a (dBm)	Desired-to-PDME Signal Ratio (D/U) (dB)
2700	-85	-82	-3
	-83	-75	-8
	-82	-58	-24
	-78.5	-50	-28.5
	-76	-62	-14
5000	-85	--	--
	-83	-79	-4
	-82	-61	-21
	-78.5	-66	-12.5
	-76	-82	-6
Y-Mode, PDME Pulse-Pair Spacing = 18 μ s			
2700	-85	-42	-43
	-83	-32	-51
	-82	-22	-60
	-78.5	-22	-56.5
	-76	-22	-54
5000	-85	-22	-63
	-83	-67	-16
	-82	-63	-19
	-78.5	-45	-33.5
	-76	-64	-12

^aThe expected time to display range exceeded the susceptibility criterion or the DME 190 would not display range for signal levels exceeding the values in the table.

ranged from -3 to -28.5 dB for 2700 pp/s and -4 to -21 dB for 5000 pp/s. However, the Y-mode interrogator appeared more tolerant of the PDME interfering signals than the X-mode DME 190: $D/U \leq -43$ dB for 2700 pp/s and $D/U \leq -12$ dB for 5000 pp/s.

Despite variations in the data, it appears that the DME 190 will display range information within λ seconds when $D/U = 8$ dB, for nondecodable, cochannel, PDME signals. Based on the measured data, a less stringent bound on susceptibility to this type of signal could be $-3 < D/U < 8$ dB.

For adjacent-channel conditions, the data were inconsistent, although there were trends (FIGURES 33-36). The Y-mode DME 190 displayed the range in an expected time that did not exceed λ seconds for : 1) decodable and nondecodable PDME PRF's of 2700 and 5000 pp/s, 2) frequency separations between the desired and PDME signal greater than or equal to 0.9 MHz, and 3) $D/U \leq 0$ dB. However, the X-mode DME 190 PDME signal failed to display the range within λ seconds for the above conditions, but some results indicated performance improved with increasing PDME signal level. The Y-mode results were similar with either decodable or nondecodable PDME signals. X-mode results for decodable and nondecodable signals were also comparable. The inconsistency of the measured results between X-mode and Y-mode operation and between performance in the presence of decodable and nondecodable MLS signals is unexplainable at present.

The adjacent-channel results can be related to D/U bounds and thus can be compared against the existing TACAN/DME adjacent-channel siting criteria of -42 dB for 1-MHz separation and -50 dB for 2-MHz separation. (Note that this comparison is arbitrary, since the existing criteria pertain to acquiring range lock with a tracking loop interrogator, and the NARCO DME 190 criterion pertains to time to display range.) For X-mode and a D/U of -42 dB, the DME 190 displayed range within λ seconds, but for Y-mode the expected time to display range remained less than λ seconds for a D/U of -60 dB.

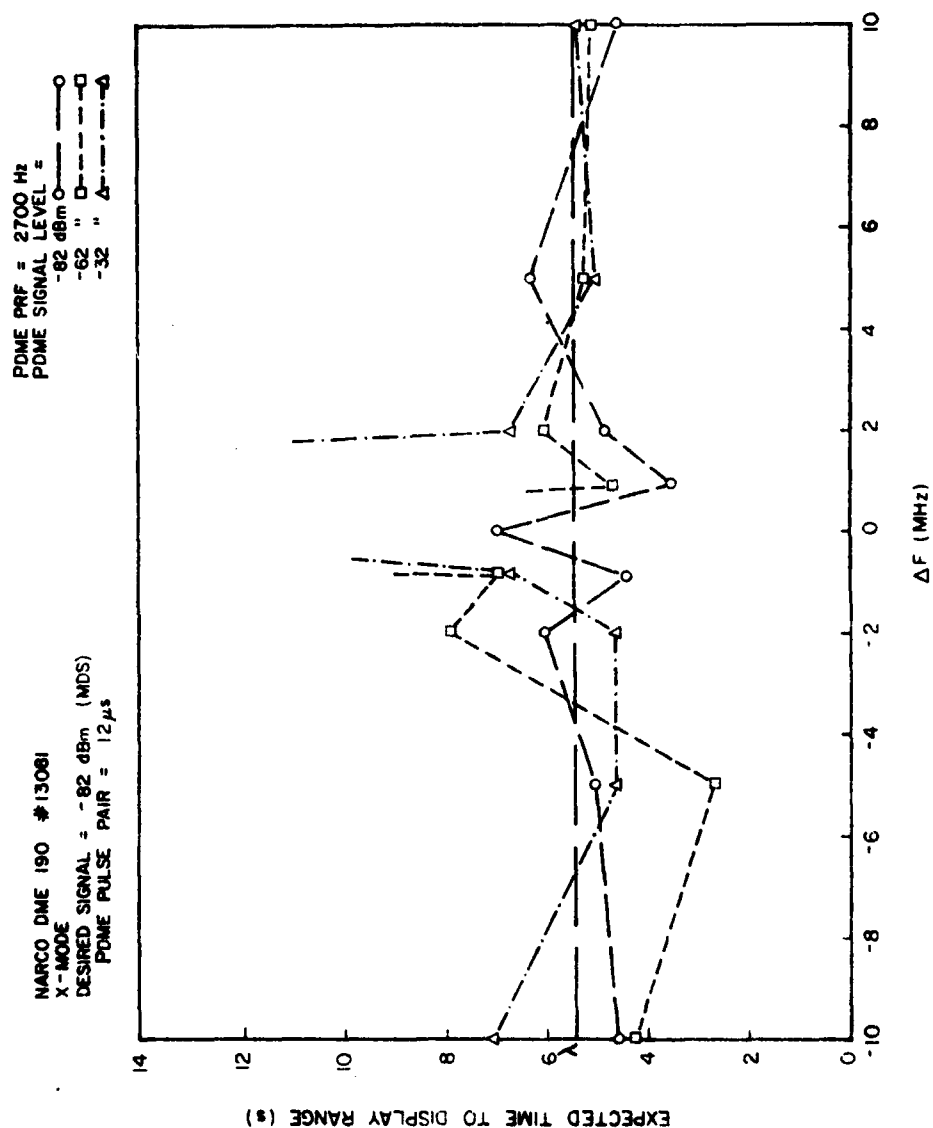


FIGURE 55. NARCO DME 190 (X-MODE) ADJACENT-CHANNEL PERFORMANCE IN THE PRESENCE OF PDME, 12- μ s PULSE PAIRS AT 2700 pp/s.

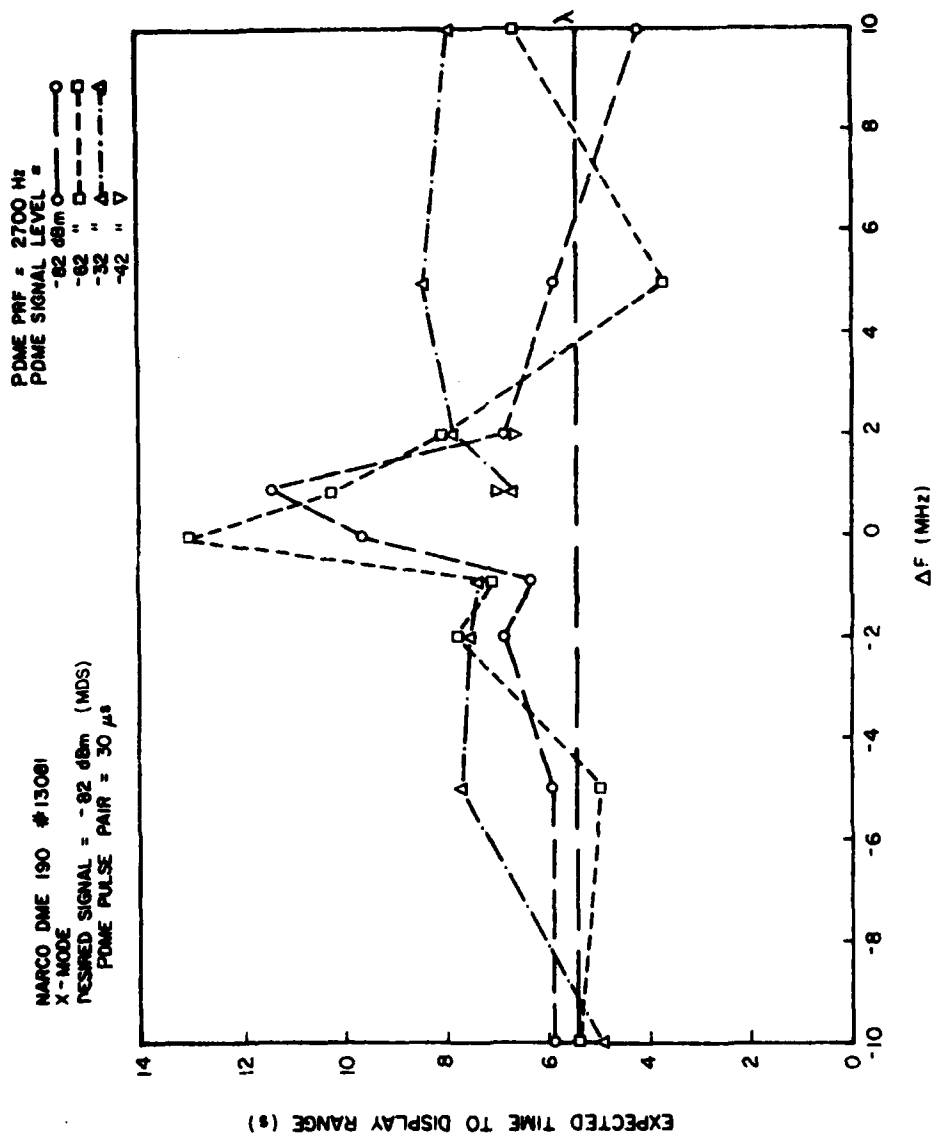


FIGURE 34. NARCO DME 190 (X-MODE) ADJACENT-CHANNEL PERFORMANCE IN THE PRESENCE OF PDME, 30- μ s PULSE PAIRS AT 2700 pp/s.

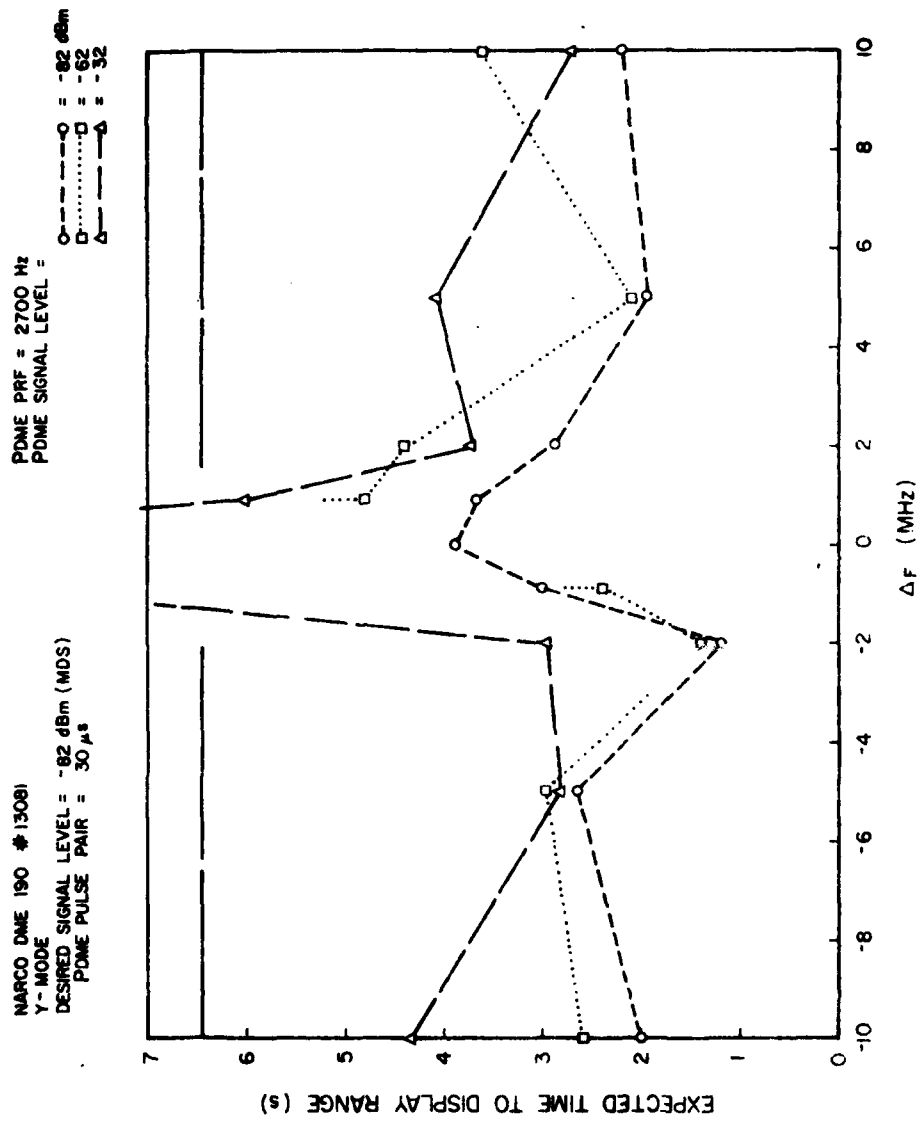


FIGURE 55. NARCO DME 190 (Y-MODE) ADJACENT-CHANNEL PERFORMANCE IN THE PRESENCE OF PDME, 30- μ s PULSE PAIRS AT 2700 pp/s.

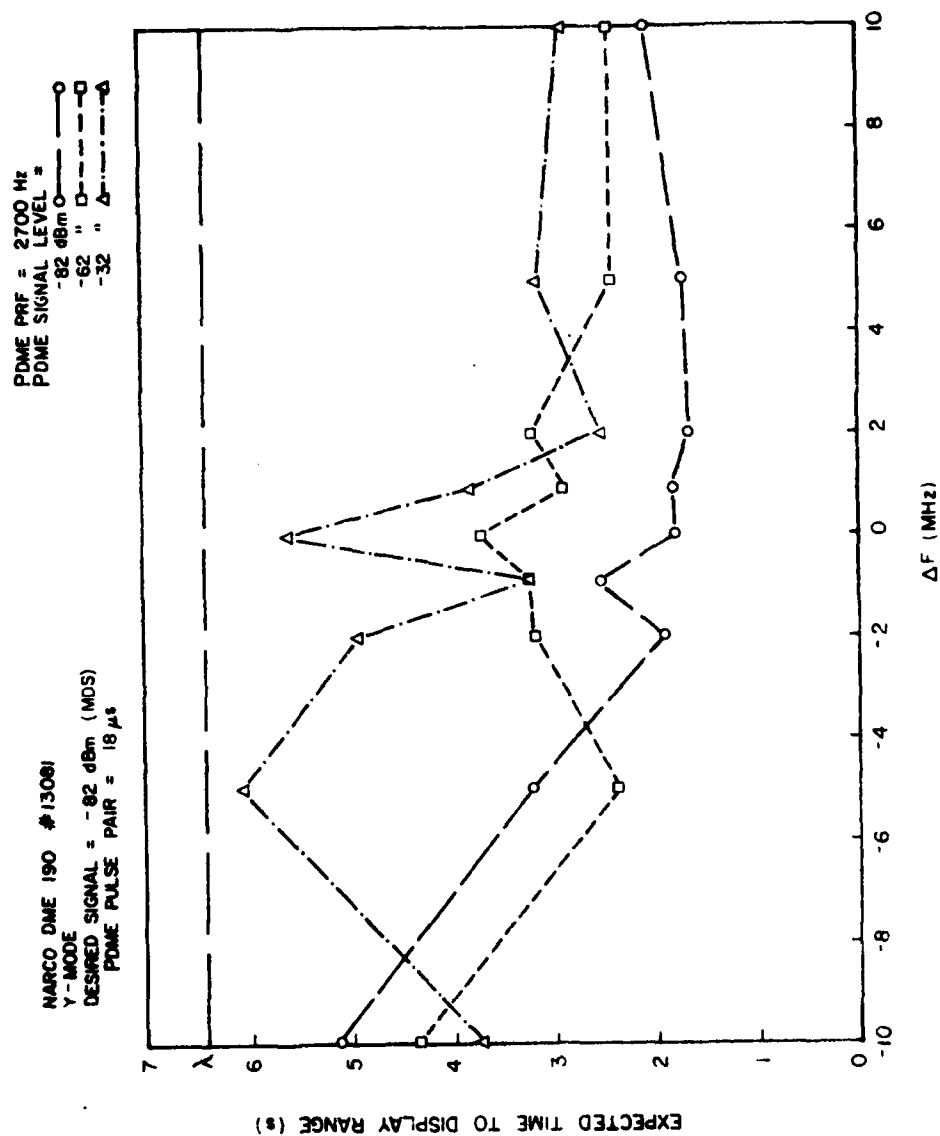


FIGURE 36. NARCO DME 190 (Y-MODE) ADJACENT-CHANNEL PERFORMANCE IN THE PRESENCE OF PDME, 18- μ s PULSE PAIRS AT 2700 pp/s.

This interrogator appeared to behave like the AN/ARN-84 and KING KDM 7000. It satisfied the TACAN cochannel siting criterion but in X-mode did not satisfy the adjacent-channel criteria. The measured results indicate that this equipment, when operated in X-mode, was one of the most susceptible to the PDME signals.

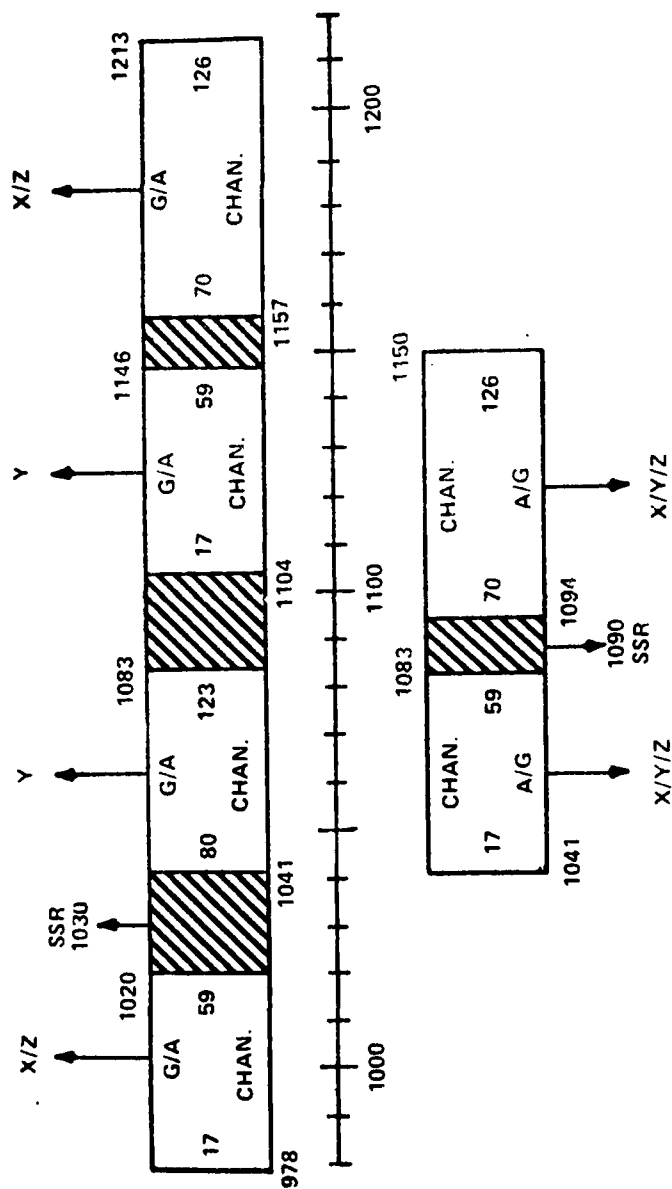
PDME CHANNEL PLANS

The findings derived from the measured data have a direct influence on the development and application of an acceptable PDME channel plan. As stated in Section 2, the 960-1215 MHz band has channels for TACAN/DME X- and Y-mode service as well as the frequencies for secondary surveillance radar. Assuming a one-for-one pairing with the MLS angle guidance channels, 200 additional channels will be required for PDME in this frequency band. The United States, the United Kingdom (UK), and the Federal Republic of Germany (FRG) have suggested channel plans in their proposals to the ICAO (References 1, 5, and 4).

The U.S. proposal is shown in FIGURE 37. Existing but as yet unassigned Y-mode channels (including those allocated for ILS-DME) would provide approximately half the needed channels. The remainder would make use of existing X-mode frequency pairs with an 18- μ s pulse-pair spacing. These are termed Z-mode channels. The existing X-mode ILS-DME channels would also be designated for dual ILS/MLS PDME operation.

The United Kingdom proposal is shown in TABLE 8. This proposal uses the 40 ILS-DME channels (18-56 even, X and Y) and then creates new channels by multiplexing channels 17X-56X, 87X-126X with new modes "XV" and "XW". The pulse-pair spacings are 18 μ s for XV-mode and 42 μ s for XW-mode.

The FRG proposal is shown in TABLE 9. Two-hundred channels are obtained with the 20 X-mode and 20 Y-mode ILS-DME channel pairings. For both the X-mode and Y-mode pairings, four additional channels are created by multiplexing. The proposed pulse-pair spacings are 14, 16, 18, 20, 22, 24, 26, and 28 μ s.



PULSE SPACING:

X CHANNELS: A/G 12 μ s, G/A 12 μ s

Y CHANNELS: A/G 36 μ s, G/A 30 μ s

Z CHANNELS: A/G 18 μ s, G/A 18 μ s (FOR EXAMPLE)

FIGURE 37. U.S. PROPOSED L-BAND PDME CHANNEL PLAN (REFERENCE 1).

TABLE 8

U.K. PROPOSED L-BAND PDME CHANNEL PLAN (REFERENCE 3)

Channel No.	Angle Frequency (MHz)	Ranging				Channel
		G-to-A Transmission		A-to-G Transmission		
		Freq (MHz)	Code (μs)	Freq (MHz)	Code (μs)	
0	5031.0	979	12	1042	12	18X
1	5031.3	1105	30	1042	36	18Y
2	5031.6	981	12	1044	12	20X
3	5031.9	1107	30	1044	36	20Y
4	5032.2	983	12	1046	12	22X
⋮	⋮	⋮	⋮	⋮	⋮	⋮
38	5042.4	1017	12	1080	12	56X
39	5042.7	1143	30	1080	36	56Y
40	5043.0	979	18	1042	18	18XV
41	5043.3	979	42	1042	42	18XW
42	5043.6	981	18	1044	18	20XV
43	5043.9	981	42	1044	42	20XW
⋮	⋮	⋮	⋮	⋮	⋮	⋮
78	5054.4	1017	18	1080	18	56XV
79	5054.7	1017	42	1080	42	56XW
80	5055.0	978	18	1041	18	17XV
81	5055.3	978	42	1041	42	17XW
⋮	⋮	⋮	⋮	⋮	⋮	⋮
118	5066.4	1016	18	1079	18	55XV
119	5066.7	1016	42	1079	42	55XW
120	5067.0	1175	18	1112	18	88XV
121	5067.3	1175	42	1112	42	88XW
⋮	⋮	⋮	⋮	⋮	⋮	⋮
158	5078.4	1213	18	1150	18	126XV
159	5078.7	1213	42	1150	42	126XW
160	5079.0	1174	18	1111	18	87XV
161	5079.3	1174	42	1111	42	87XW
⋮	⋮	⋮	⋮	⋮	⋮	⋮
198	5090.4	1212	18	1149	18	125XV
199	5090.7	1212	42	1149	42	125XW

TABLE 9

FRG PROPOSED L-BAND PDME CHANNEL PLAN (REFERENCE 4)

Channel No.	Interrogation Frequency (MHz) and Pulse-Pair Spacing (μs)	Reply Frequency (MHz) and Pulse-Pair Spacing (μs)
18 X ^a	1042 (12)	979 (12)
X-1 ^b	1042 (16)	979 (16)
X-2	1042 (20)	979 (20)
X-3	1042 (24)	979 (24)
X-4	1042 (28)	979 (28)
18 Y ^a	1042 (36)	1105 (30)
Y-1	1042 (14)	1105 (14)
Y-2	1042 (18)	1105 (18)
Y-3	1042 (22)	1105 (22)
Y-4	1042 (26)	1105 (26)
⋮	⋮	⋮
56 X	1080 (12)	1017 (12)
X-1	1080 (16)	1017 (16)
X-2	1080 (20)	1017 (20)
X-3	1080 (24)	1017 (24)
X-4	1080 (28)	1017 (28)
56 Y	1080 (36)	1143 (30)
Y-1	1080 (14)	1143 (14)
Y-2	1080 (18)	1143 (18)
Y-3	1080 (22)	1143 (22)
Y-4	1080 (26)	1143 (26)

^aX, Y correspond to existing TACAN/DME channel designations.

^bX-1, Y-2 . . . , Y-1, Y-2, . . . correspond to proposed MLS PDME multiplexed channels.

All the proposals use the pulse-pair signal format. Only the FRG does not recommend sharpening the leading edge of the first pulse.

INTERFERENCE PROTECTION

References 1, 3, and 4 imply that the rules governing TACAN/DME protection can apply to MLS PDME protection. The implication also is made that there will be no interference between TACAN/DME and MLS PDME because different pulse-pair spacings are used; i.e., the same argument as used for X- and Y-mode.

Reference 4 states the following with regard to interference protection and channel assignment in a particular area:

"For the time multiplex channels there is no restriction for channel assignment in a particular area, they can be located even in direct vicinity. Only one exception must be noted. If the difference in the g/a frequencies of two transponders operating in X- or Y-mode is 63 MHz, they must be treated in a special way. This is the same case for the existing X-0 and Y-0 channeling plan of Annex 10.

Separation in distance for two stations with the same frequency and code is the same as used today for cochannel DME ground stations. The existing rules for adjacent-channel separations are also valid for DLS^a channel assignments."

All the references, as illustrated by the above quotation, indicate an optimistic attitude toward the ability to add 200 more channels in the 960-1215 MHz band, assigning these channels to MLS PDME transponders, and avoiding intrasystem MLS PDME and intersystem TACAN/MLS PDME interference problems. This optimism is based on the assumptions that no interference protection is required between systems on the same channel frequency but transmitting with different pulse-pair spacings.

The assumption comes from the present protection rules for mutual X- and Y-mode operation. However, these rules have never been applied or evaluated.

^a FRG DME (based) Landing System.

Those few Y-mode installations in the United States were not given channel assignments indiscriminately, as the rules would allow, but were given assignments that FAA hoped would minimize any potential interference between the X and Y systems (i.e., maximum possible frequency separation). There was no attempt to validate the rule that X and Y ground systems having the same receiver frequency could operate in close proximity to one another without degrading the performance of either system.

The system proposals assume that whatever protection is satisfactory for TACAN/DME is also satisfactory for MLS PDME. Since the range accuracy requirement for MLS PDME is more stringent than for TACAN/DME, it is possible that more protection is required to guarantee MLS PDME performance than for TACAN/DME performance.

The documentation does not present any evidence to give reasonable confidence or even an indication that compatibility will result between TACAN/DME and MLS PDME DME just by changing pulse-pair spacing.

INTERROGATOR RESULTS

The preceding discussions of the measured data showed that the ability of TACAN and DME interrogators to acquire range and azimuth lock can be impaired by PDME interfering signals. TABLE 10 summarizes the limiting conditions under which all the TACAN and DME interrogators will still acquire range or azimuth data. These conditions are presented as a function of PDME PRF, signal format decodability, and frequency separation between the desired and undesired signal. Comparison of conditions for the two types of interrogators shows that TACAN (azimuth) equipments would succumb to the interference from PDME signals before the newer DME interrogators. Therefore, to assure that as a minimum, both TACAN and newer DME equipments would operate in the presence of PDME signals, it will be necessary to prevent signal conditions from exceeding the conditions listed in TABLE 10 for TACAN equipments.

TABLE 10

MINIMUM D/U THAT PERMITS TACAN AND DME INTERROGATORS TESTED
TO ACQUIRE RANGE OR AZIMUTH LOCK^a

a. PDME PRF = 2700 pp/s

	TACAN's		All DME's		New DME's ^c	
	Decodable ^b	Non-Decodable ^c	Decodable	Non-Decodable	Decodable	Non-Decodable
Cochannel	+ 5	0	0	+ 1	- 2	-10
1st Adj. Channel	-18	-18	-12	-16	-25	-43
2nd Adj. Channel	-29	-20	-42	-40	-47	-57
3rd Adj. Channel	-37	-33	-43	-42	-50	-58
4th Adj. Channel	-44	-43	-44	-44	-53	-59
5th Adj. Channel	-49	-53	-45	-47	-55	-59

b. PDME PRF = 5000 pp/s

	TACAN's		All DME's		New DME's	
	Decodable	Non-Decodable	Decodable	Non-Decodable	Decodable	Non-Decodable
Cochannel	+ 6	+ 1	+ 4	+ 2	- 2	- 6
1st Adj. Channel	-10	- 9	-14	-10	-18	- 9
2nd Adj. Channel	-20	-21	-38	-23	-42	-19
3rd Adj. Channel	-29	-31	-39	-35	-45	-34
4th Adj. Channel	-40	-41	-41	-36	-50	-46
5th Adj. Channel	-48	-51	-43	-37	-54	-57

c. PDME PRF = 10,000 pp/s

	TACAN's		All DME's		New DME's	
	Decodable	Non-Decodable	Decodable	Non-Decodable	Decodable	Non-Decodable
Cochannel	+ 7	+ 4	+ 5	+ 5	+ 4	- 2
1st Adj. Channel	d	-	-	-	-	-
2nd Adj. Channel	-	-	-	-	-	-
3rd Adj. Channel	-	-	-	-	-	-
4th Adj. Channel	-	-	-	-	-	-
5th Adj. Channel	-	-	-	-	-	-

^aBased on worst-case data.^bPDME signals decodable by TACAN/DME.^cPDME signals not decodable by TACAN/DME.^dAdjacent-channel data not taken.^eExclude NARCO UDI 4 and KING KN 60C.

Assume that conditions exceeding the limiting conditions in TABLE 10 for TACAN equipments are the conditions to be avoided when installing PDME transponders. The limiting conditions would then be considered when assigning channels to the PDME transponders.

Also, assume that the PDME signal rate will not exceed 2700 pp/s and a PDME transponder will be assigned an existing X- or Y-mode channel. Therefore, the limiting signal conditions for TACAN operation in the presence of PDME signals will be those in the first column of TABLE 10a. These conditions are more stringent (except for cochannel conditions) than the conditions for TACAN channel assignment. This implies more difficulty in assigning PDME equipments to X- or Y-mode channels than assigning TACAN/DME equipments on these same channels.

Now assume a PDME transponder will operate on a multiplexed XZ- or YZ-mode channel. The limiting conditions would be as specified in the third column of TABLE 10a. These conditions also are more stringent (except for cofrequency conditions) than TACAN channel assignment conditions. This implies more difficulty in assigning XZ- or YZ-mode channels than in assigning TACAN channels. Also, the conditions for decodable PDME signals (X- or Y-mode channels) and nondecodable PDME signals (XZ- and YZ-mode channels) are comparable. Therefore, there appears to be no major channel assignability advantage of a multiplexed channel over a normal X- or Y-mode channel.

Furthermore, if the interfering rate of the PDME signal increases above 2700 pp/s, the limiting conditions become more difficult to obtain and channel assignments would become more difficult to make.

It should be noted that Reference 10 has standards for cochannel and adjacent-channel operation, but Reference 11 does not require verification of the interrogator characteristics for all interrogators which would insure protection against adjacent-channel (TACAN) interference. Thus, possibly many operating TACAN/DME interrogators do not meet the existing adjacent-channel

standards despite manufacturer satisfaction of the minimum operational characteristics. These equipment may perform at, above or below the adjacent-channel standards stated in Reference 10. Therefore it may be misleading to assume that it would be more difficult (except for cofrequency conditions) to assign channels to PDME than to assign them to TACAN/DME. It is in fact more difficult in view of existing standards, but it is a relative unknown when compared to actual performance of existing TACAN/DME equipment in the presence of adjacent-channel (TACAN) interference.

Regardless of the TACAN/DME susceptibility to adjacent-channel TACAN signals, the limiting conditions for operation in the presence of PDME or TACAN signals would be similar (i.e., D/U ratios must be considered). The PDME use of nondecodable pulse-pair spacings does not automatically create 200 additional channels, but perhaps only 200 separate ways to identify existing channels. This is the main disadvantage of previously proposed channel plans which assume a nondecodable pulse-pair spacing (pulse-multiplexing) signal format.

TRANSPONDER DATA

A modified RTB-2 (EDMAC Receiver), and the AN/GRN-9C transponders were tested to determine their susceptibility to interference from the PDME cosine/cosine² signal format. Susceptibility was measured in terms of decoder aperture, reply efficiency, and echo-suppression deadtime. Reply efficiency was measured as a function of desired signal level and rate and PDME signal level and rate. Reply efficiency is defined as the desired synchronous reply rate divided by the desired interrogation rate.

Cochannel Results for AN/GRN-9C with X-Mode Desired Signal. As shown in FIGURE 38, the AN/GRN-9C decoder aperture extends approximately from 9 to 14 μ s. Pulse-pairs with spacing greater than 16 μ s will not decode.

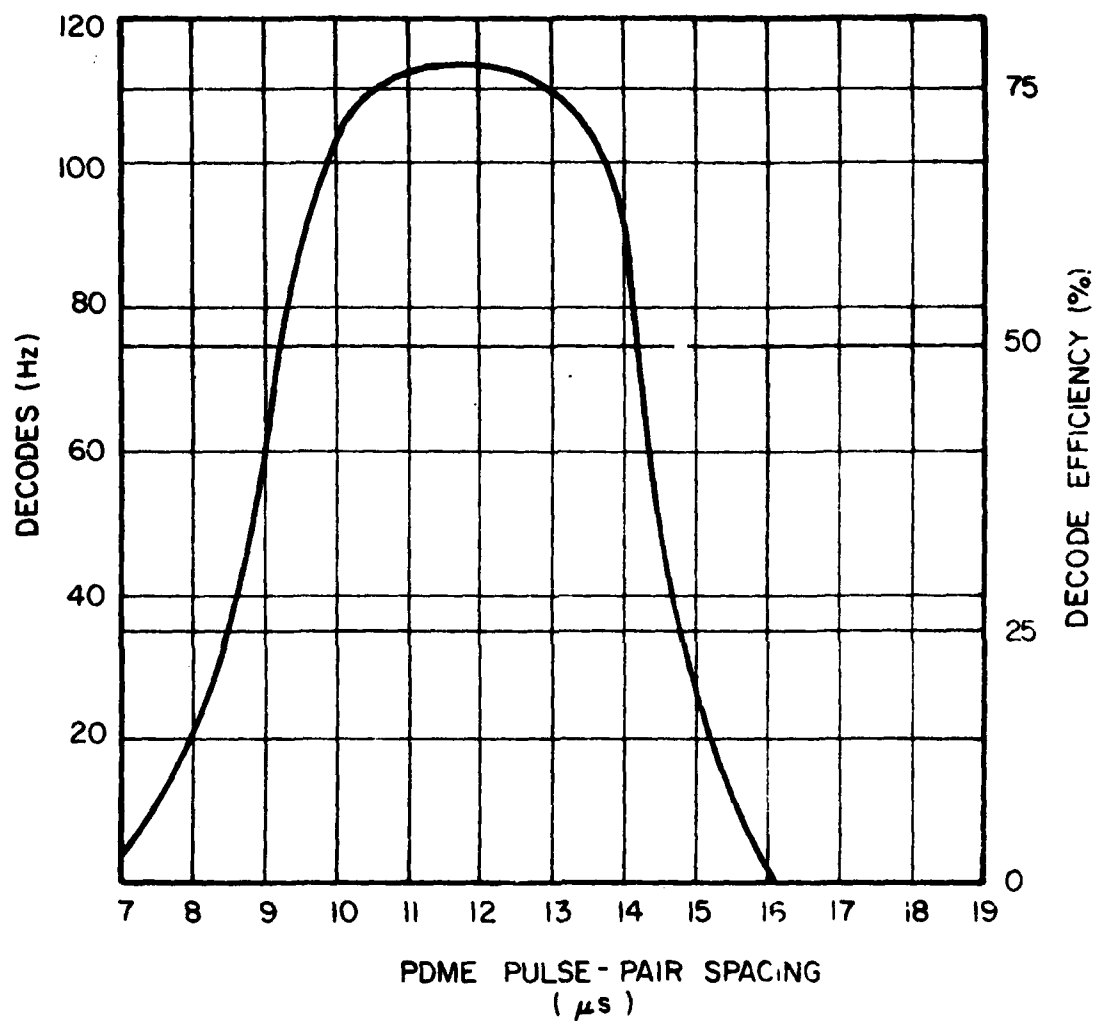


FIGURE 38. AN/GRN-9C DECODER APERTURE AS MEASURED USING A PDME SIGNAL AT -81 dBm AND 150 PULSE-PAIR TRANSMISSION RATE.

FIGURES 39-44 show reply efficiency of the AN/GRN-9C as a function of PDME cosine/cosine² pulse-pair spacing, PRF, and signal level as well as desired signal level and PRF. FIGURES 39, 41, 42, and 44 show how the transponder reply efficiency varies as a function of PDME cosine/cosine² pulse-pair spacing and signal rate when the desired signal has a rate of 3300 Hz and a power level at the receiver input equal to minimum discernible signal (MDS) and 6 dB above MDS. For these measurements MDS was determined based upon a 60% reply efficiency with a 400 Hz desired interrogation rate.

Since the desired signal is at MDS, FIGURE 39 could represent the reply efficiency to an interrogator at the edge of the coverage volume. In this figure, reply efficiency of the transponder remains approximately constant and appears independent of the PDME pulse-pair spacing. However, for PDME signal levels 20 to 40 dB above the desired signal, the reply efficiency has its greatest value when the interfering pulse-pair spacing is 18 μ s. The interference by decodable signals^a generates more deadtime in the receiver than the nondecodable (18 μ s) interference which only generates echo-suppression deadtime.

Decoder-generated deadtime is approximately 72 μ s and is measured from the leading edge of the first pulse of the interrogation to the end of the deadtime. Interrogations arriving during the decoder deadtime will not generate a reply from the transponder. FIGURE 40 shows the length of time the echo-suppression circuitry reduces sensitivity of the receiver as a function of the power level, with pulse-pair spacing as a parameter. This time is measured from the first pulse of the pulse-pair to the point when the receiver has recovered nominal sensitivity. For the pulse-pair spacings shown, the echo-suppression effect is shorter than the deadtime generated by a decode. Also, since the length and amount of the sensitivity reduction depend on the power level of the signal, the actual effect of the echo-suppression caused by the interference depends on the particular environmental conditions at each potential victim transponder.

^a12- μ s pulse-pairs and 13- μ s pulse-pairs. The 13- μ s pulse-pairs represent signals with pulse-pair spacings just within the aperture of the decoder.

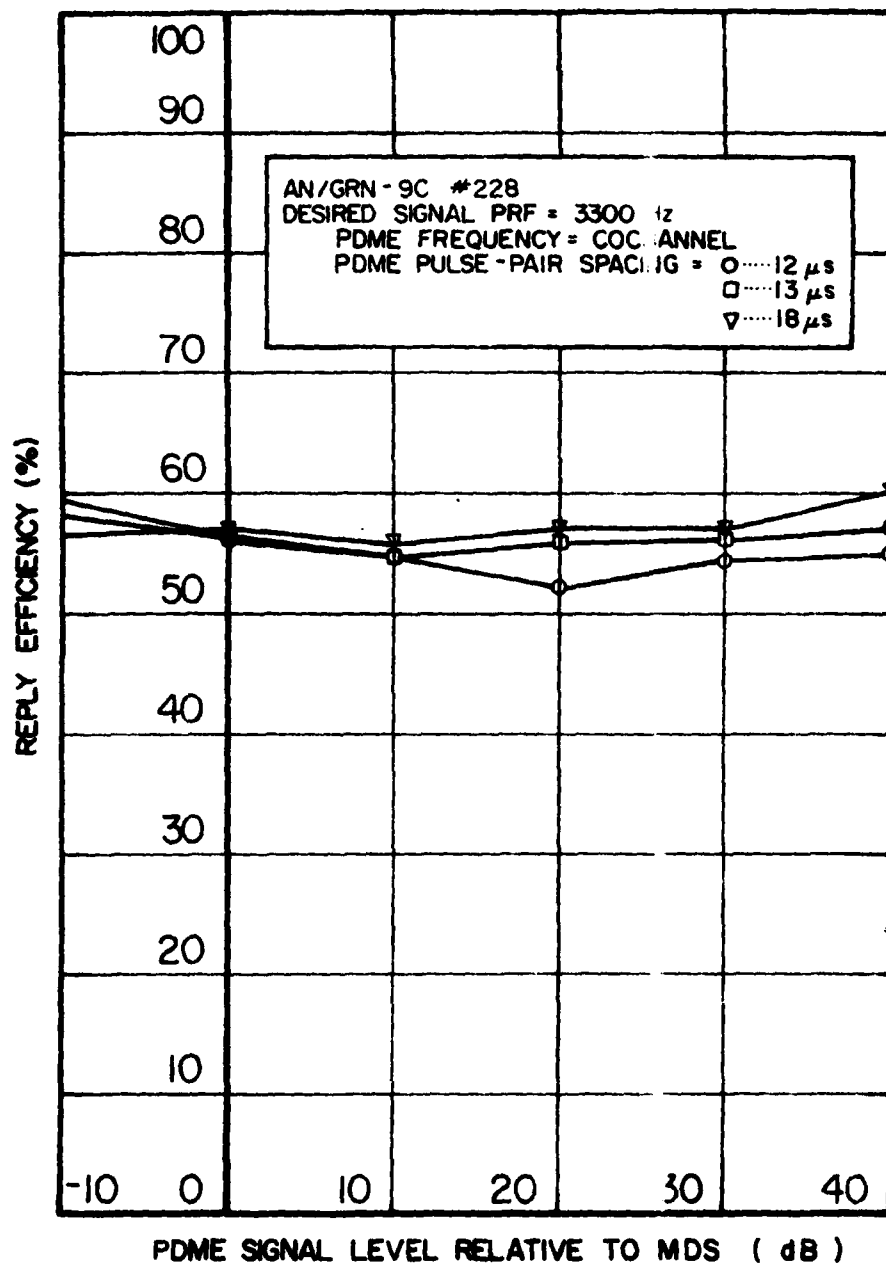


FIGURE 39. AN/GRN-9C PERFORMANCE WITH -96 dBm DESIRED SIGNAL AND PDME PRF OF 1000 Hz.

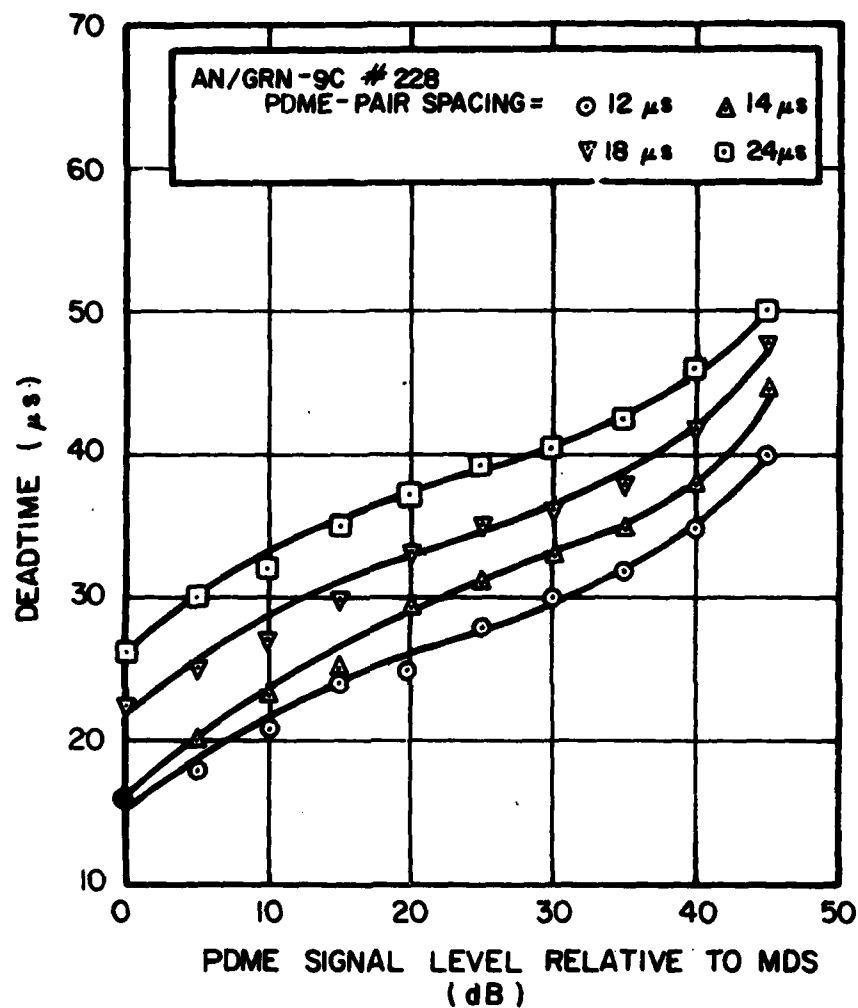


FIGURE 40. AN/GRN-9C DEADTIME (GENERATION).

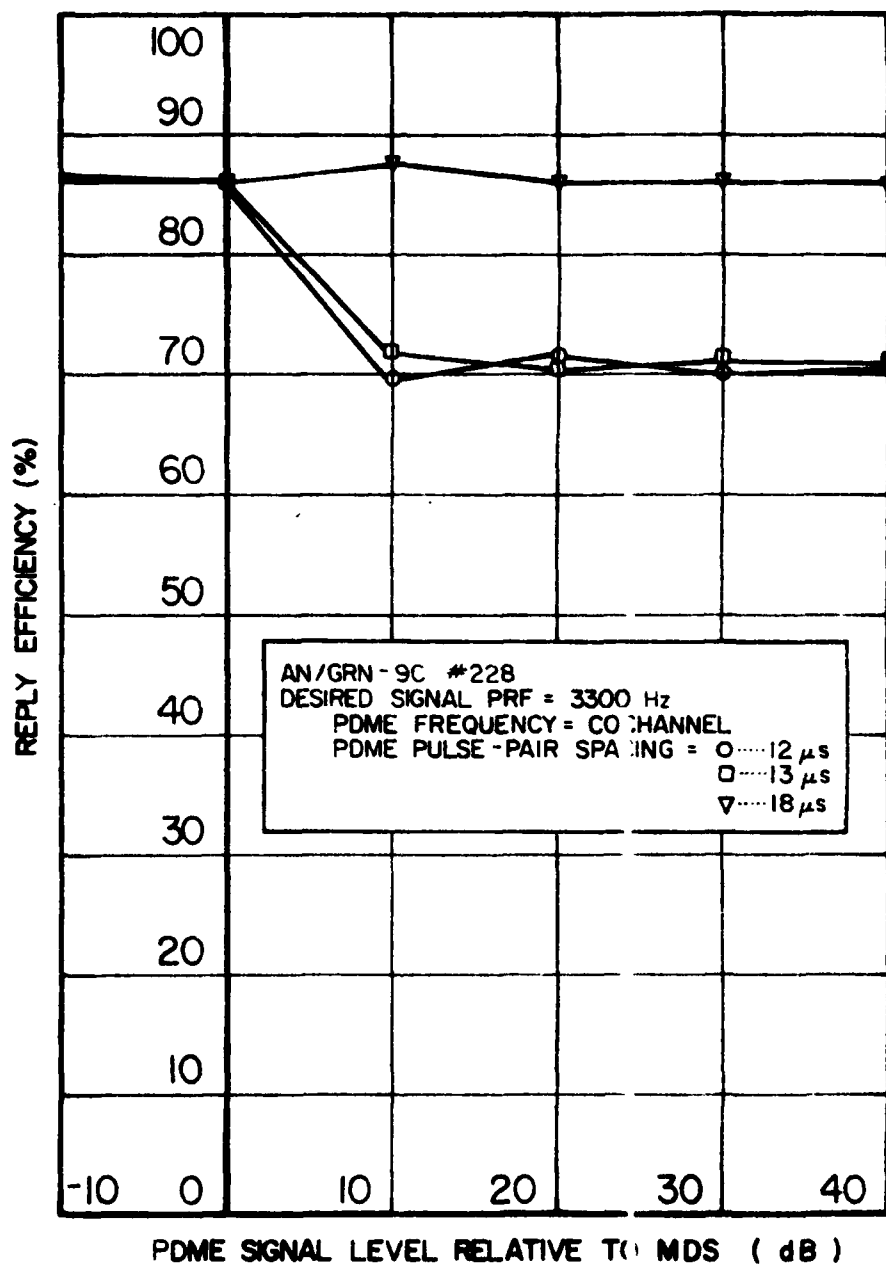


FIGURE 41. AN/GRN-9C PERFORMANCE WITH -90 dBm DESIRED SIGNAL AND PDME PRF OF 1000 Hz.

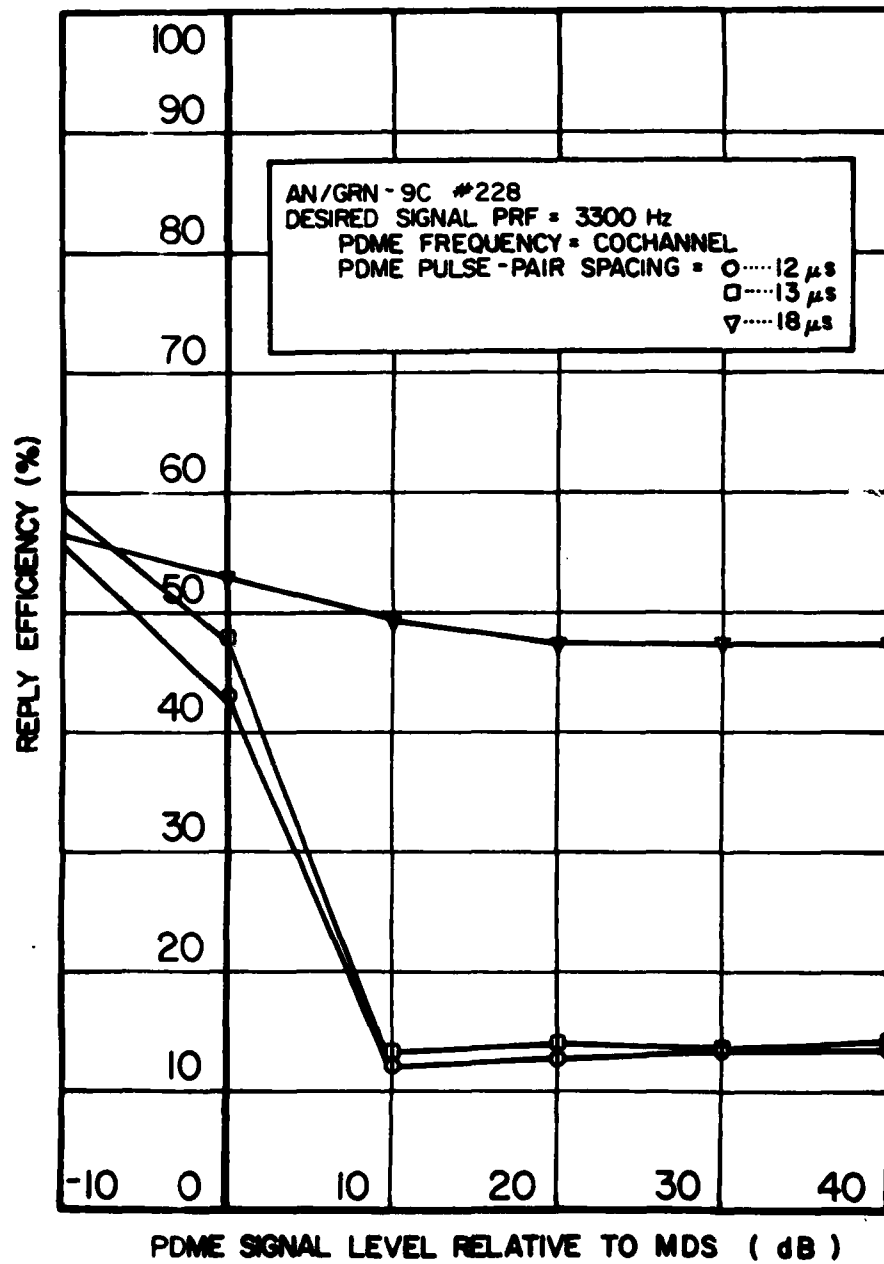


FIGURE 42. AN/GRN-9C PERFORMANCE WITH -96 dBm DESIRED SIGNAL AND PDME PRF OF 5000 Hz.

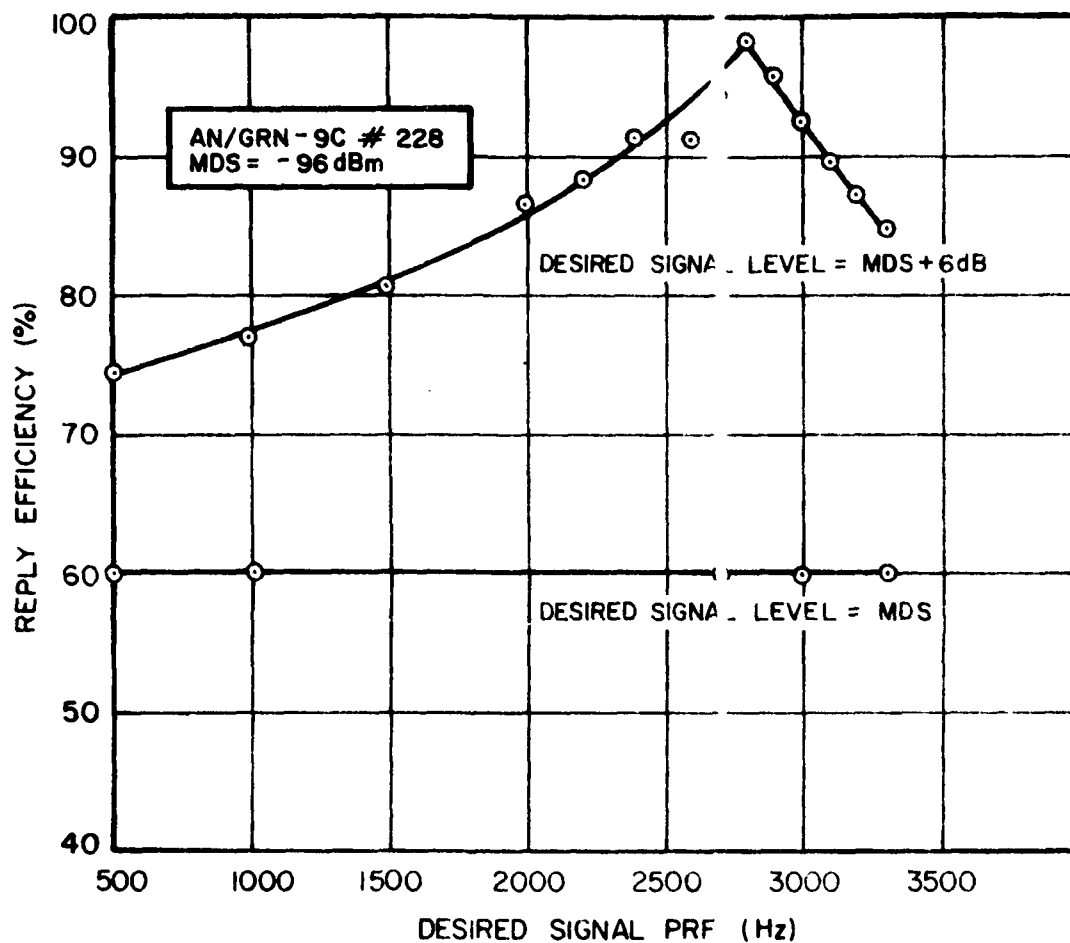


FIGURE 43. AN/GRN-9C PERFORMANCE WITH NO INTERFERENCE.

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THE SUSCEPTIBILITY OF REPRESENTATIVE TACAN AND DME EQUIPMENTS T--ETC(U)

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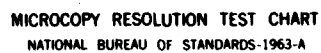
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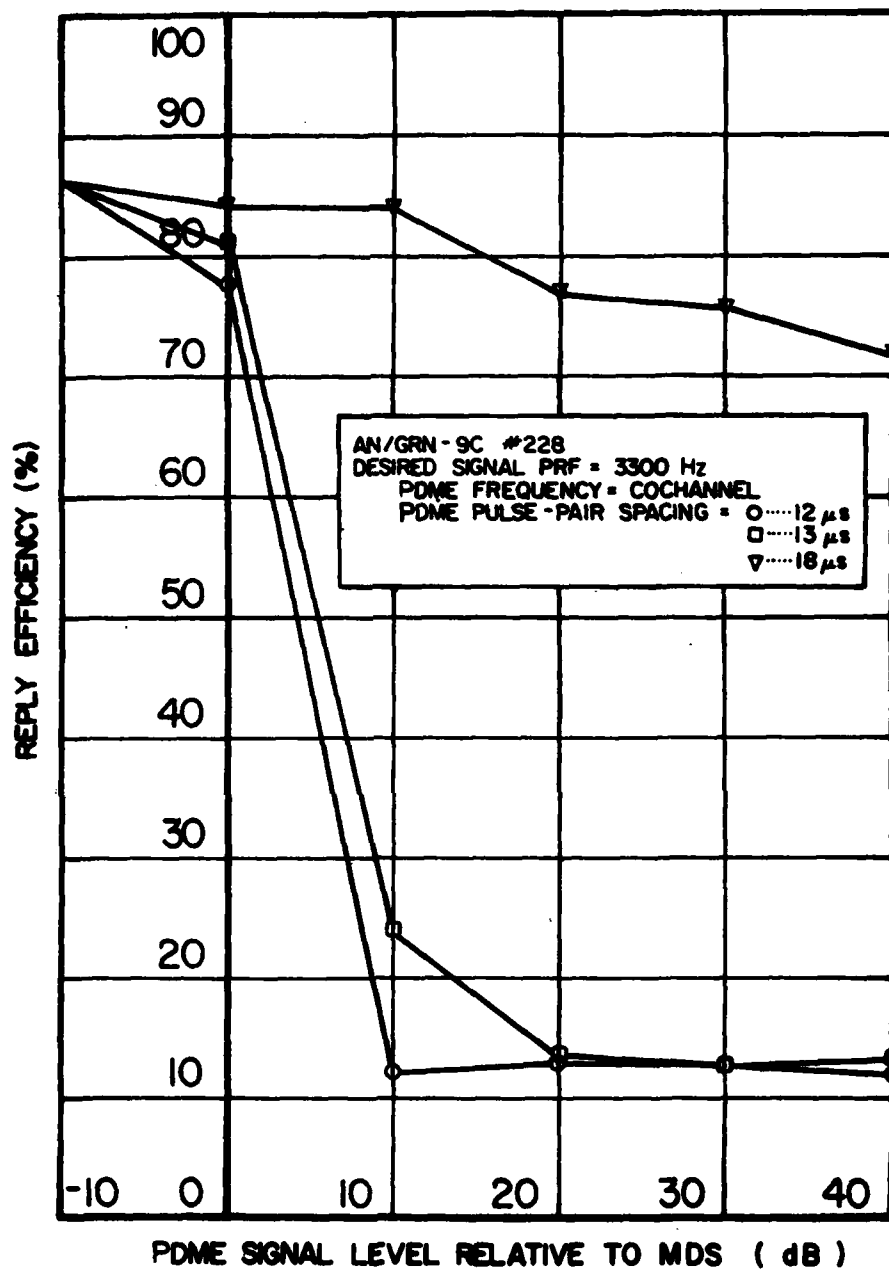


FIGURE 44. AN/GRN-9C PERFORMANCE WITH -90 dBm DESIRED SIGNAL AND PDME PRF OF 5000 Hz.

In FIGURE 41 the desired signal is 6 dB above MDS, representing an interrogator within the coverage volume, and thus, the reply efficiency is higher than for a weak signal. As the PDME signal level increases, the reply efficiency of the desired signal decreases for the cases where the interference consists of 12- and 13- μ s pulse-pairs. The decrease is more dramatic in FIGURE 46 than in FIGURE 39 because the transponder has to activate the reply-rate overload circuitry to maintain the duty cycle of 2700 MHz. This causes a decrease in receiver sensitivity and a resulting decrease in desired-signal reply efficiency. The 18- μ s pulse-pairs are not decodable and thus no decrease in sensitivity and no corresponding decrease in reply efficiency occur. The echo-suppression deadtime generated by these low-duty-cycle pulse-pairs appears not to affect the reply efficiency by masking the valid interrogations.

As the interfering signal rate is increased, the reply efficiency decreases for 12- and 13- μ s pulse-pairs even though the desired signal is at MDS (see FIGURE 42). With an interfering rate of 5000 Hz the decode rate exceeds 2700 Hz, as in FIGURE 41, and reply efficiency reduces to approximately 12%. Eighteen-microsecond pulse-pairs at the 5000-Hz rate reduce the desired-signal reply efficiency 3-6% compared with the 1000-Hz rate (FIGURE 39) as the PDME signal is increased. This plot definitely shows the consequences of decodable interference and the apparently less dramatic effect of nondecodable pulse-pairs. However, the reply efficiency for the desired signal conditions is at least 60% when no interference is present, as shown in FIGURE 43. Even with 18- μ s pulse-pairs the reply efficiency is 3-12% below this minimum value in FIGURES 39 and 42.

The last case is shown in FIGURE 44. Here the desired signal is 6 dB above MDS and the interference rate is 5000 Hz. Again, in the presence of decodable interference, the desired signal has a reply efficiency of 12%. For the non-decodable interferences, the desired signal reply efficiency decreases more than 10% from the nominal 85% (see FIGURE 43). Thus, as the interfering signal rate increases the reply efficiency will decrease, despite the nondecodability of the format. This reply efficiency reduction is due to the interference-generated echo-suppression deadtime that masks desired interrogations.

The previous figures described reply efficiency as a function of PDME signal level, pulse-pair spacing, transmission rate, and desired signal level with desired signal rate held constant. FIGURES 45 through 50 show reply efficiency as a function PDME level and spacing with desired signal rate as a parameter. FIGURE 45 shows that with a decodable interference rate of 1000 Hz, the reply efficiency remains at least 60% for desired rates less than 2700 Hz. For a desired rate greater than 2700 Hz the reply efficiency is less than 60%. The interference rate, however, is low enough not to cause a significant change in reply efficiency as the interfering signal level increases. As FIGURE 43 shows, the reply efficiency is 60% for all desired signal rates of interest when the desired signal level is at MDS.

FIGURE 46 shows, for the same conditions, reply efficiency with the desired signal level 6 dB above MDS. Only for desired PRF's of 500 and 1000 Hz does the reply efficiency appear to remain unchanged. For the higher desired signal rate, the reply efficiency decreases 12-14% from the level without interference but does not go below 70%.

Now consider FIGURES 46 and 48 for the case where the interference is not decodable. All other conditions are the same as in the previous two figures. FIGURES 45 and 47 appear similar. With the desired signal at MDS, it appears that decodable and nondecodable interference at 1000 Hz results in the same effect. However, FIGURE 48 shows, at most, a 5% change in reply efficiency compared with the changes in FIGURE 46.

An interference rate of 1000 Hz could be comparable to 20-40 MLS-equipped aircraft interrogating a PDME transponder, or it could be the reply rate of a lightly loaded MLS PDME transponder. As can be seen from FIGURE 48, the reply efficiency to an interrogator within the TACAN/DME transponder service volume will not change appreciably for an interference rate of 1000 Hz and a nondecoding pulse-pair spacing. This statement could be extended to include a 1000 Hz interference rate with signals containing pulse-pairs of more than

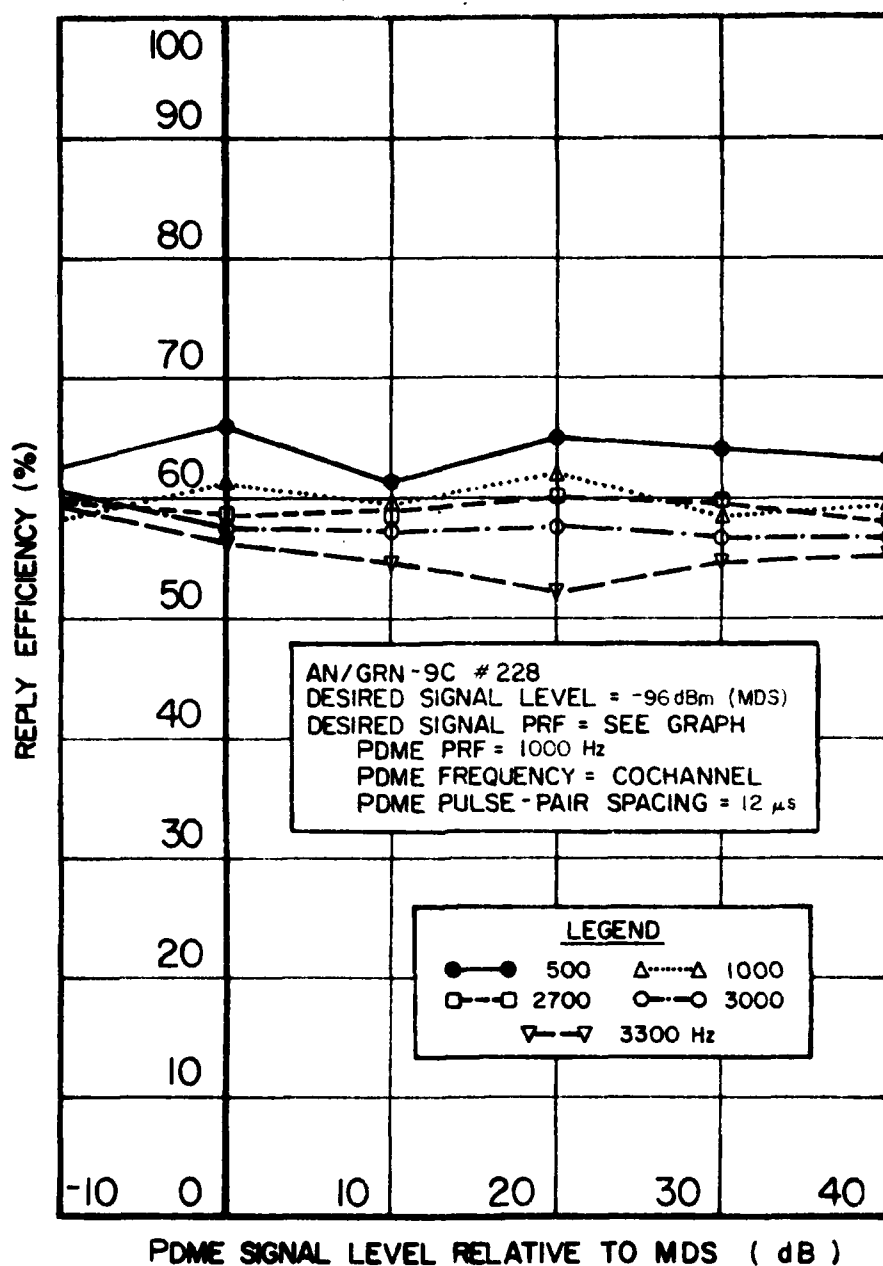


FIGURE 45. AN/GRN-9C PERFORMANCE WITH -96 dBm DESIRED SIGNAL AND PDME PRF OF 1000 Hz.

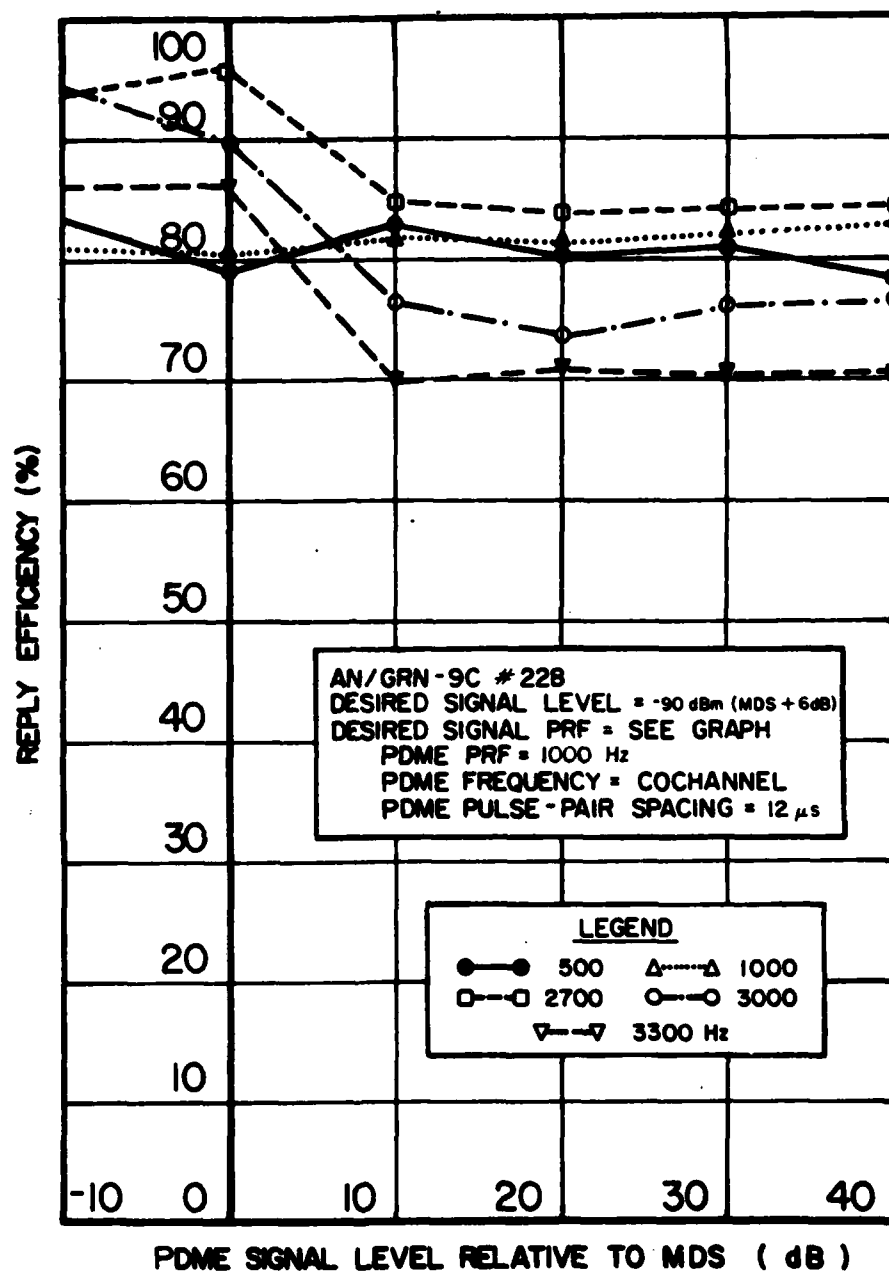


FIGURE 46. AN/GRN-9C PERFORMANCE WITH -90 dBm DESIRED SIGNAL AND PDME PRF OF 1000 Hz.

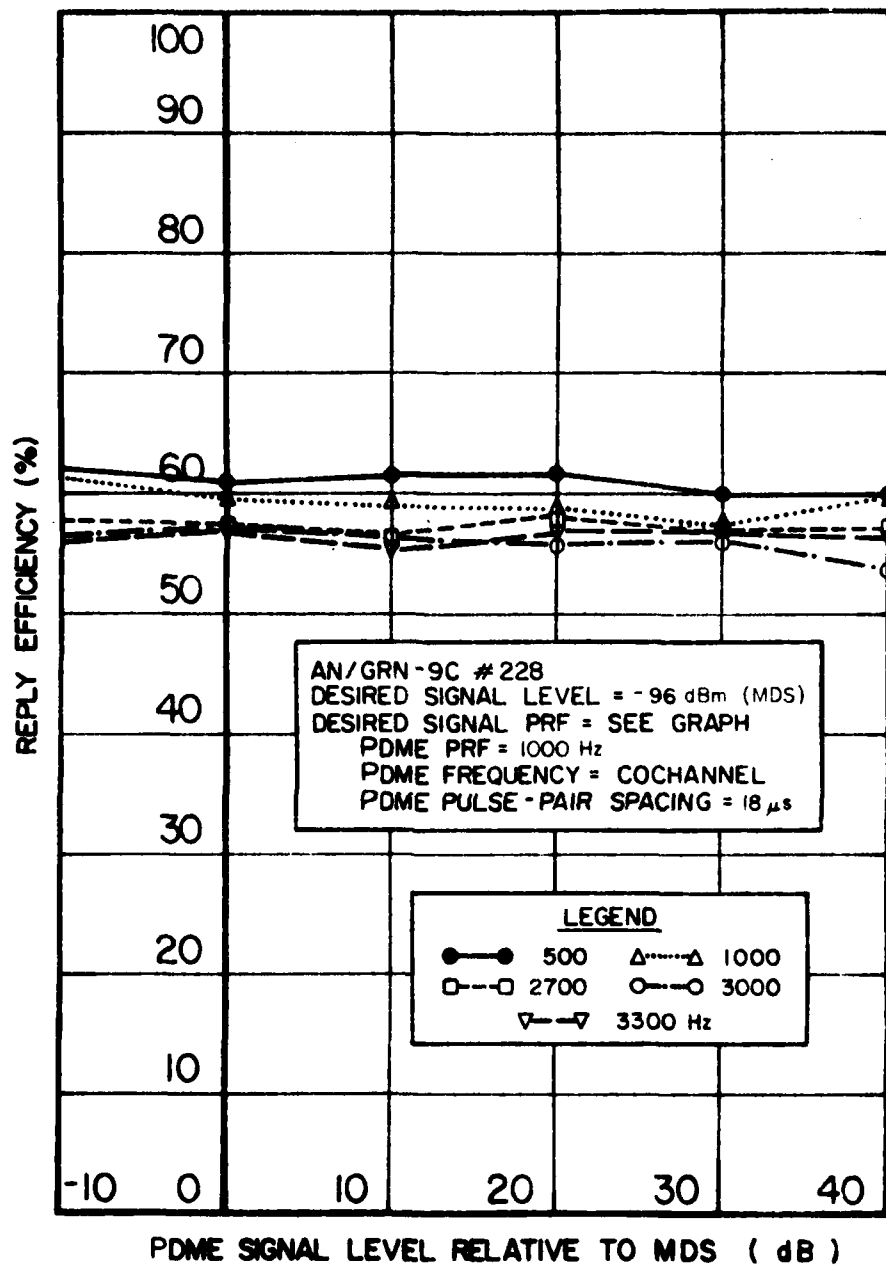


FIGURE 47. AN/GRN-9C PERFORMANCE WITH -96 dBm DESIRED SIGNAL AND PDME PRF OF 1000 Hz.

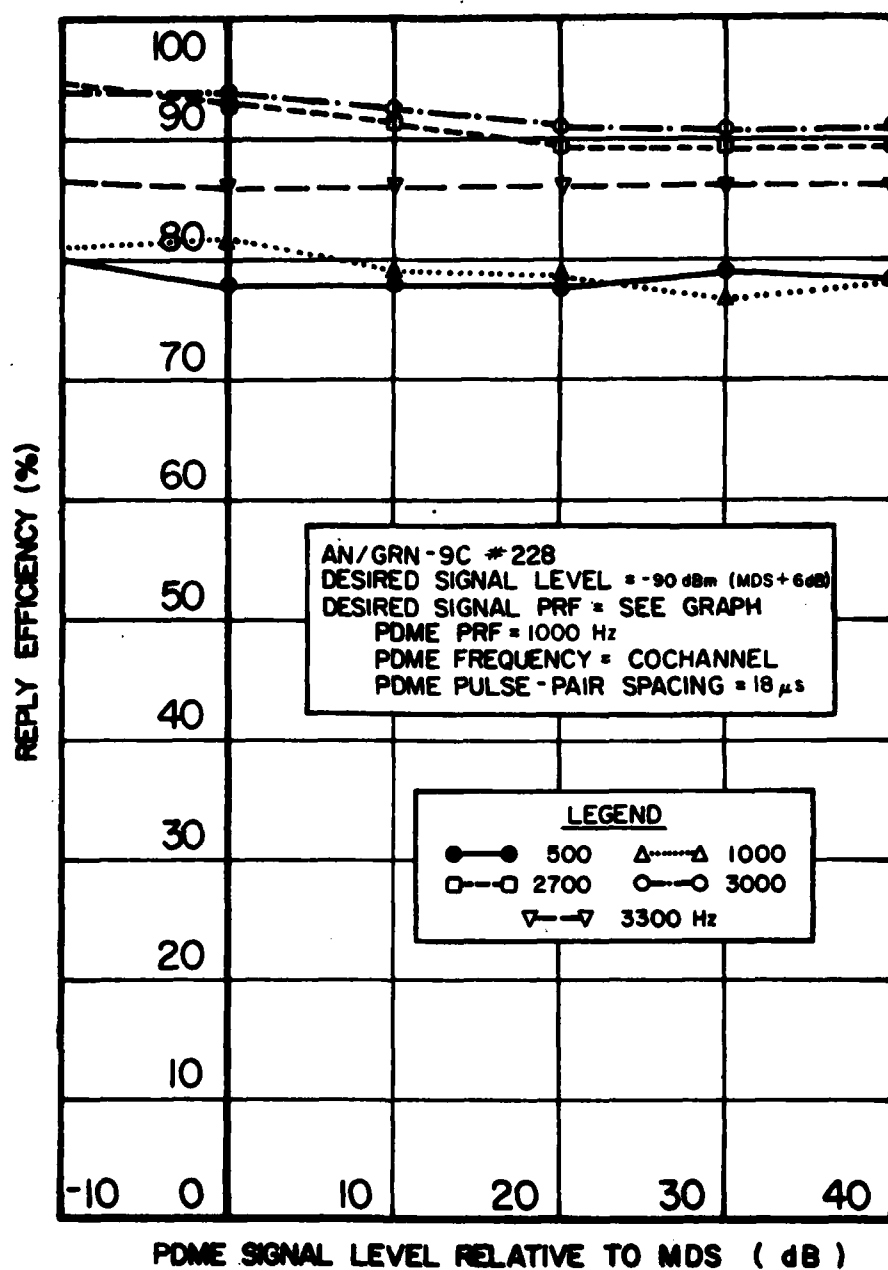


FIGURE 48. AN/GRN-9C PERFORMANCE WITH -90 dBm DESIRED SIGNAL AND PDME PRF OF 1000 Hz.

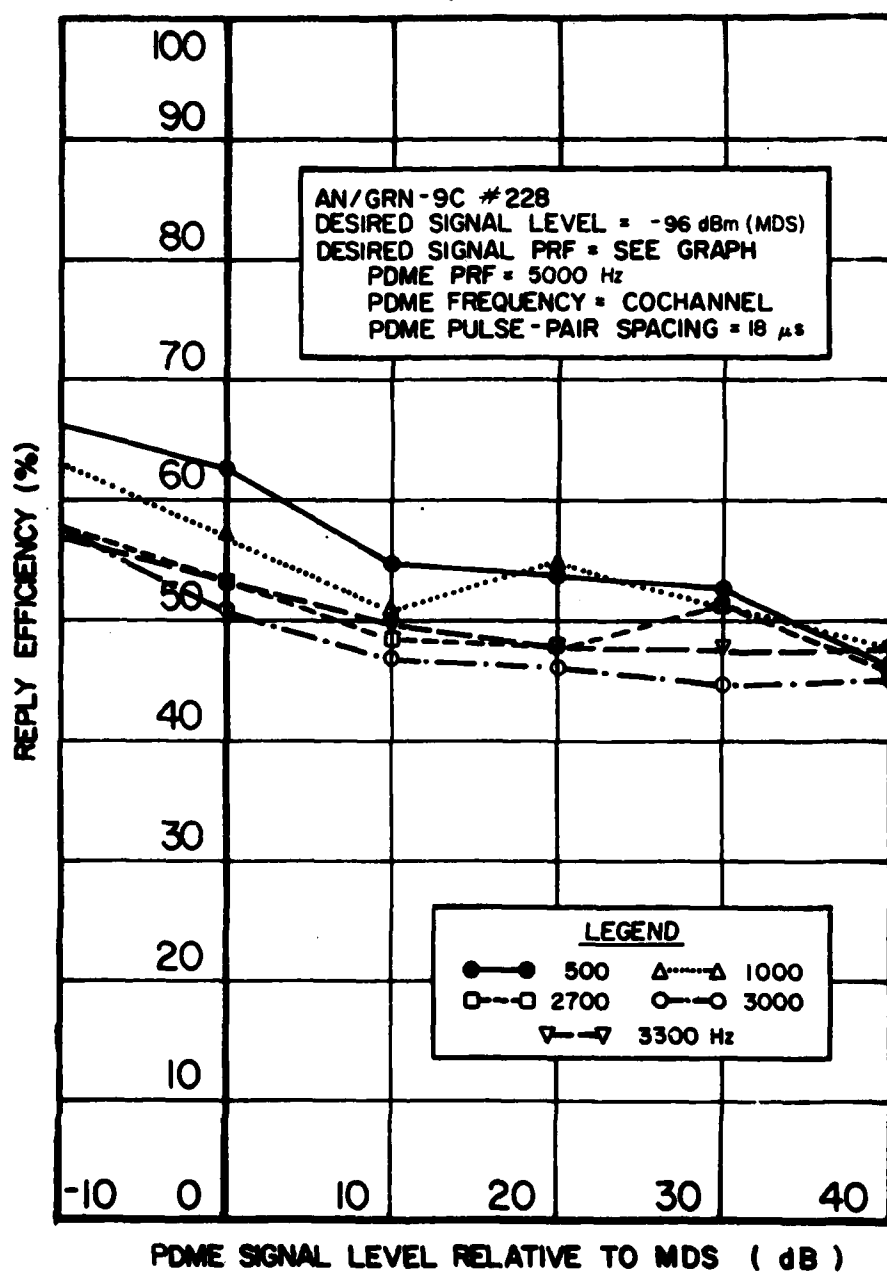


FIGURE 49. AN/GRN-9C PERFORMANCE WITH -96 dBm DESIRED SIGNAL AND PDME PRF OF 5000 Hz.

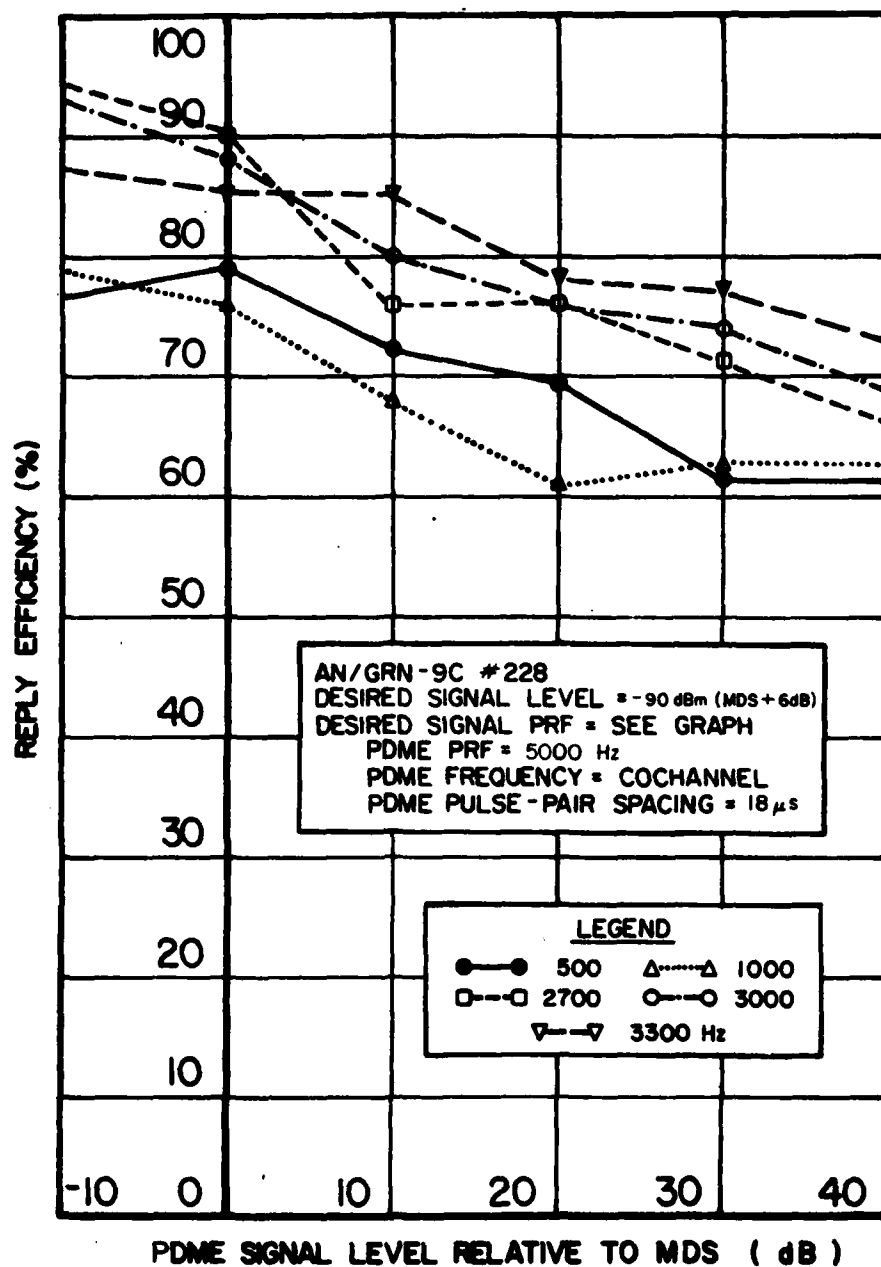


FIGURE 50. AN/GRN-9C PERFORMANCE WITH -90 dBm DESIRED SIGNAL AND PDME PRF OF 5000 Hz.

one nondecodable spacing. The interrogator, operating a little beyond the edge of the coverage volume but with a signal above equipment sensitivity, will find some decrease in reply efficiency when interference is present, depending on the loading of the desired signals (see FIGURE 47). Thus, interrogators just beyond the edge of the coverage volume may be affected more by interference, even though the interference is not decodable and of a relatively low rate.

Now consider cases where the interference rate is 5000 Hz as shown in FIGURES 49 and 50. This high interfering rate could represent the case of multiple channels on the same frequency (differentiated by a pulse-pair spacing) in the same geographic area. FIGURE 49 shows that the 5000-Hz, nondecodable interference causes the transponder reply efficiency to decrease to below 50%. The efficiency drops below 60% for all desired PRF's considered. FIGURE 50 indicates decreases in reply efficiency of 10-15% when the desired signal level is strong. The reply efficiency approaches 60% in the case of 500- and 1000-Hz desired PRF's.

The data of these last two figures show that reply efficiency can be significantly reduced with nondecodable, high-rate interference which may possibly be representative of PDME multiplexed-channeling schemes. The question which must be resolved is whether or not this high interfering rate is realizable in the same geographical area. It should be recognized that this condition is dependent upon the number of multiplexed channels on each frequency.

As a summary of AN/GRN-9C performance in the presence of PDME interference, consider FIGURES 51 and 52. Both figures show reply efficiency as a function of desired signal PRF with nondecoding interfering PRF as a parameter. Each data point on the plots was determined, based on a weighted average of performance as a function of PDME signal level.

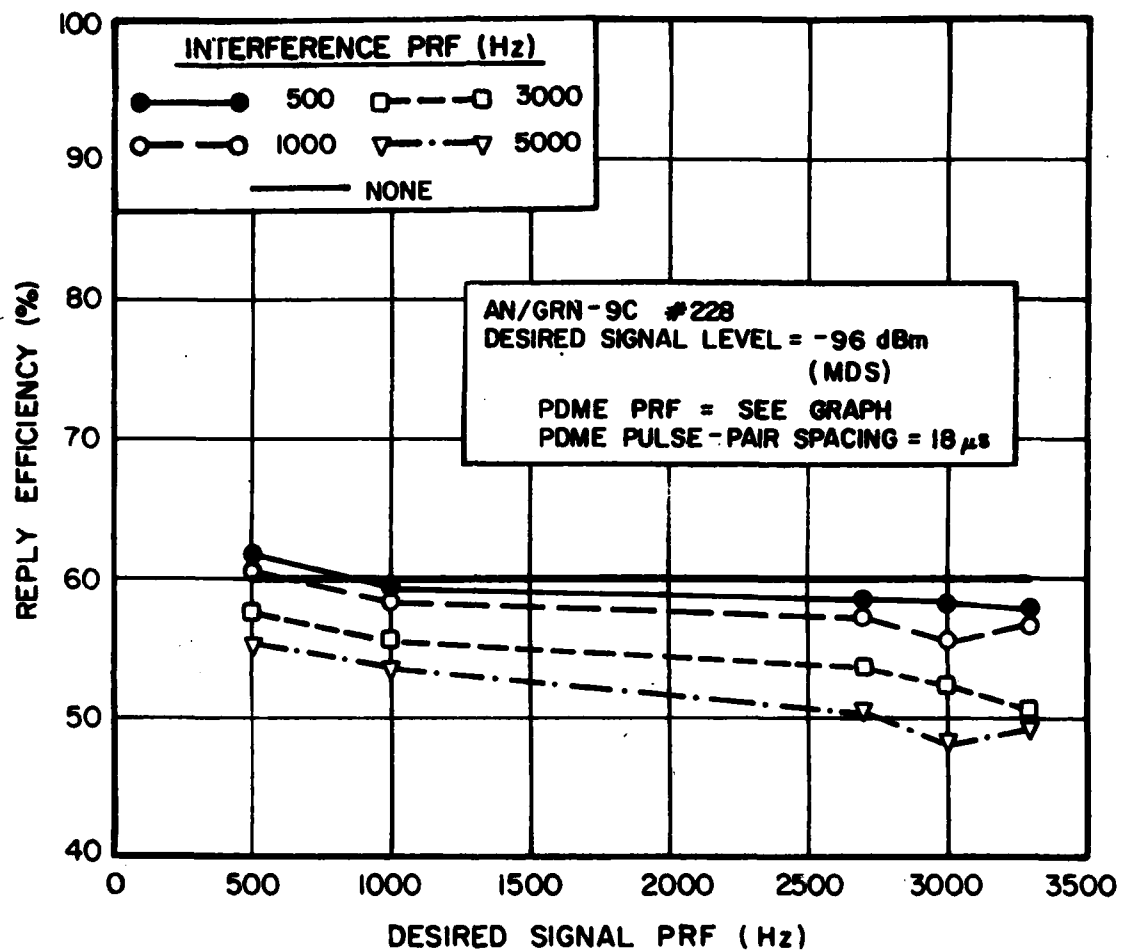


FIGURE 51. AN/GRN-9C PERFORMANCE SUMMARY, WITH -96 dBm DESIRED SIGNAL AND PDME PRF's TO 5000 Hz.

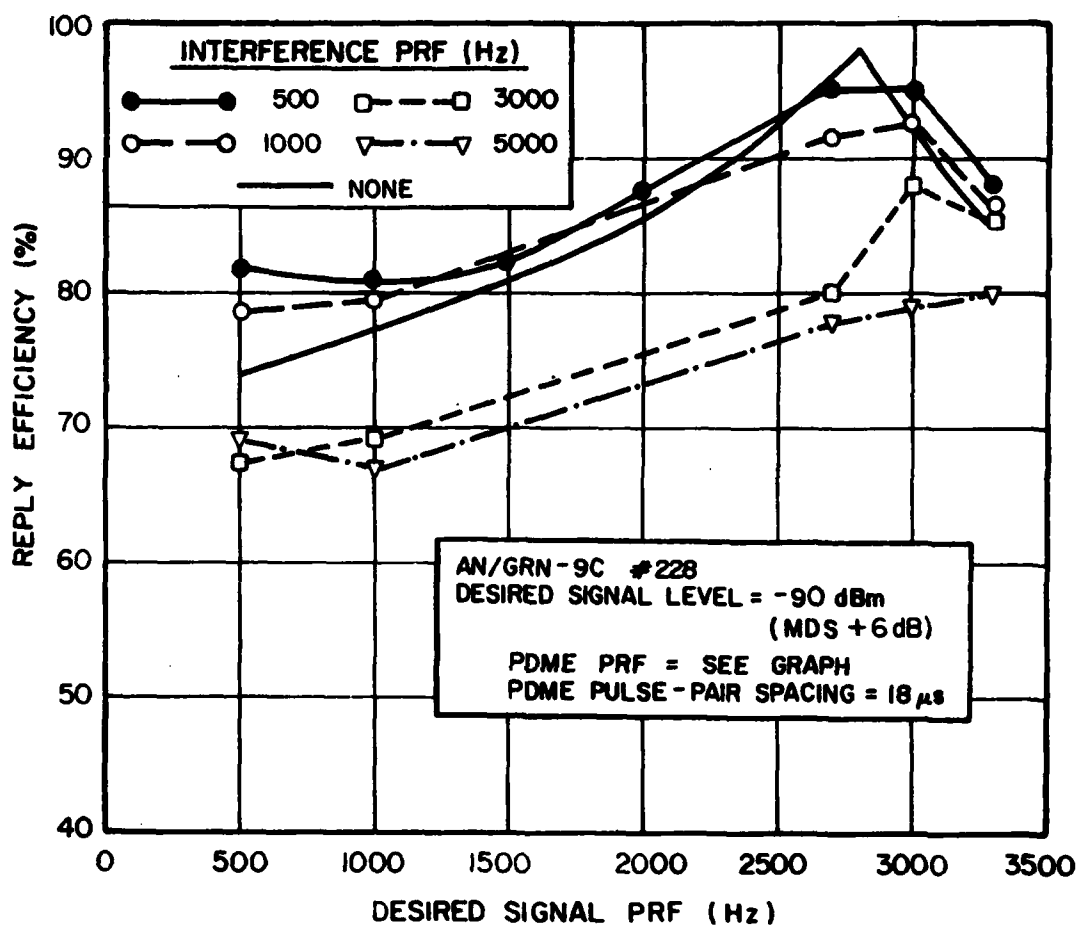


FIGURE 52. AN/GRN-9C PERFORMANCE SUMMARY, WITH -90 dBm DESIRED SIGNAL AND PDME PRF's TO 5000 Hz.

FIGURE 51 represents performance with a desired signal at MDS. It is apparent from the figure that performance degrades with even low rate interference. The decrease in reply efficiency is 1% with an interfering PRF of 500 Hz to 10% with an interfering PRF of 5000 Hz. Also, the interference affects the performance more as the desired signal PRF increases. Interference does not permit the efficiency to remain at the level of 60% which was used as a standard by NAFEC during its tests.

FIGURE 52 shows the performance with a desired signal of MDS + 6 dB. With a strong desired signal, interfering PRF's less than 1000 Hz have little effect on the reply efficiency. But when the interference rate increases to 3000 and 5000 Hz, the reply efficiency appears to decrease 10-15% from the performance with no interference present. The efficiency nonetheless remains above 67%.

These last two figures illustrate very clearly that nondecodable pulse-pairs can affect AN/GRN-9C performance. The consequences of the decrease in performance must be assessed by the FAA to determine whether interference protection criteria are required to assure the TACAN/DME transponders will not be degraded by PDME signals.

Adjacent-Channel Results for the AN/GRN-9C with X-Mode Desired Signal. The performance of the AN/GRN-9C in the presence of PDME interference that is frequency-separated from the desired-signal frequency is shown in FIGURES 53 through 60. FIGURES 53 through 66 were obtained by establishing a desired signal at MDS with a PRF of 3300 Hz. The PDME interference was 5000 Hz. This rate could represent the interrogation rate on a frequency with several multiplexed channels. Pulse-pair spacings of 12 and 24 μ s were used. Starting with the interference on-tune with the desired signal, the interfering signal level was increased in 5-dB increments and the desired reply rate was recorded. (Reply efficiency = desired replies/desired interrogators.) This procedure was repeated at frequencies of ± 0.9 , ± 2 , ± 5 , and ± 10 MHz about the desired frequency.

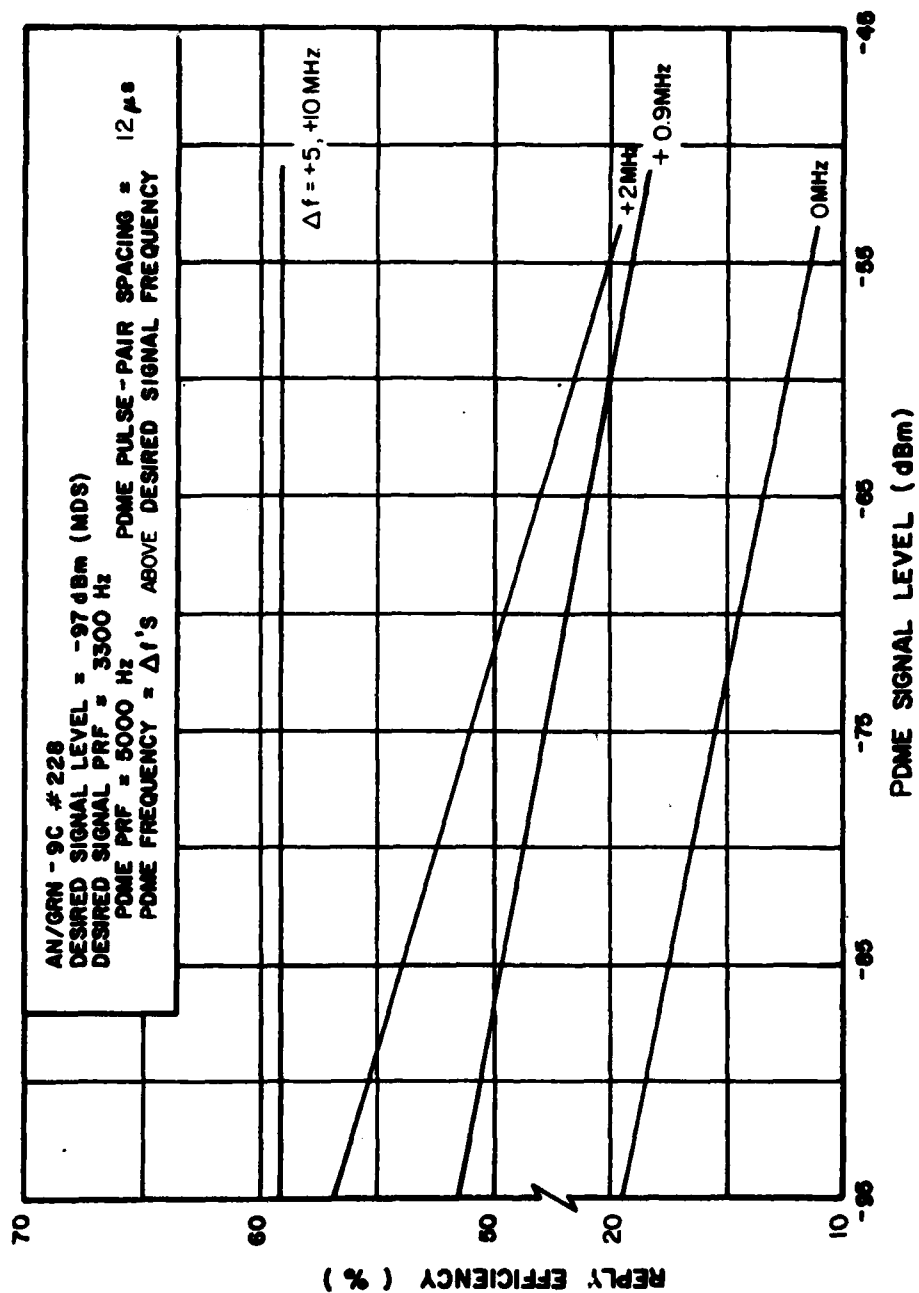


FIGURE 53. AN/GRN-9C PERFORMANCE WITH ADJACENT-CHANNEL INTERFERENCE WHEN DESIRED SIGNAL IS -97 dBm AND PDME Δf IS 0 TO +10 MHz.

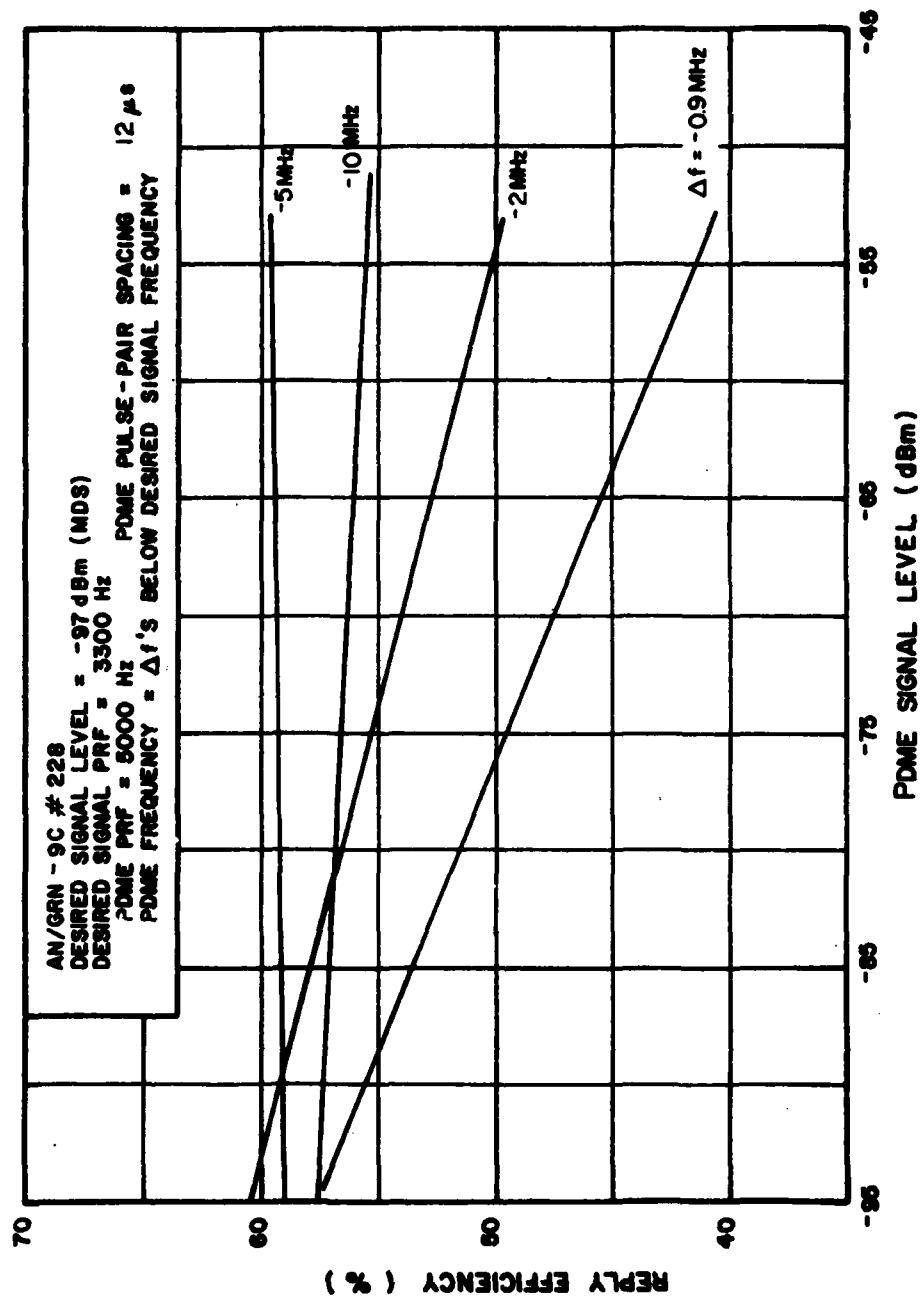


FIGURE 54. AN/GRN-9C PERFORMANCE WITH ADJACENT-CHANNEL INTERFERENCE WHEN DESIRED SIGNAL IS -97 dBm AND PDME Δf IS -0.9 TO -10 MHz.

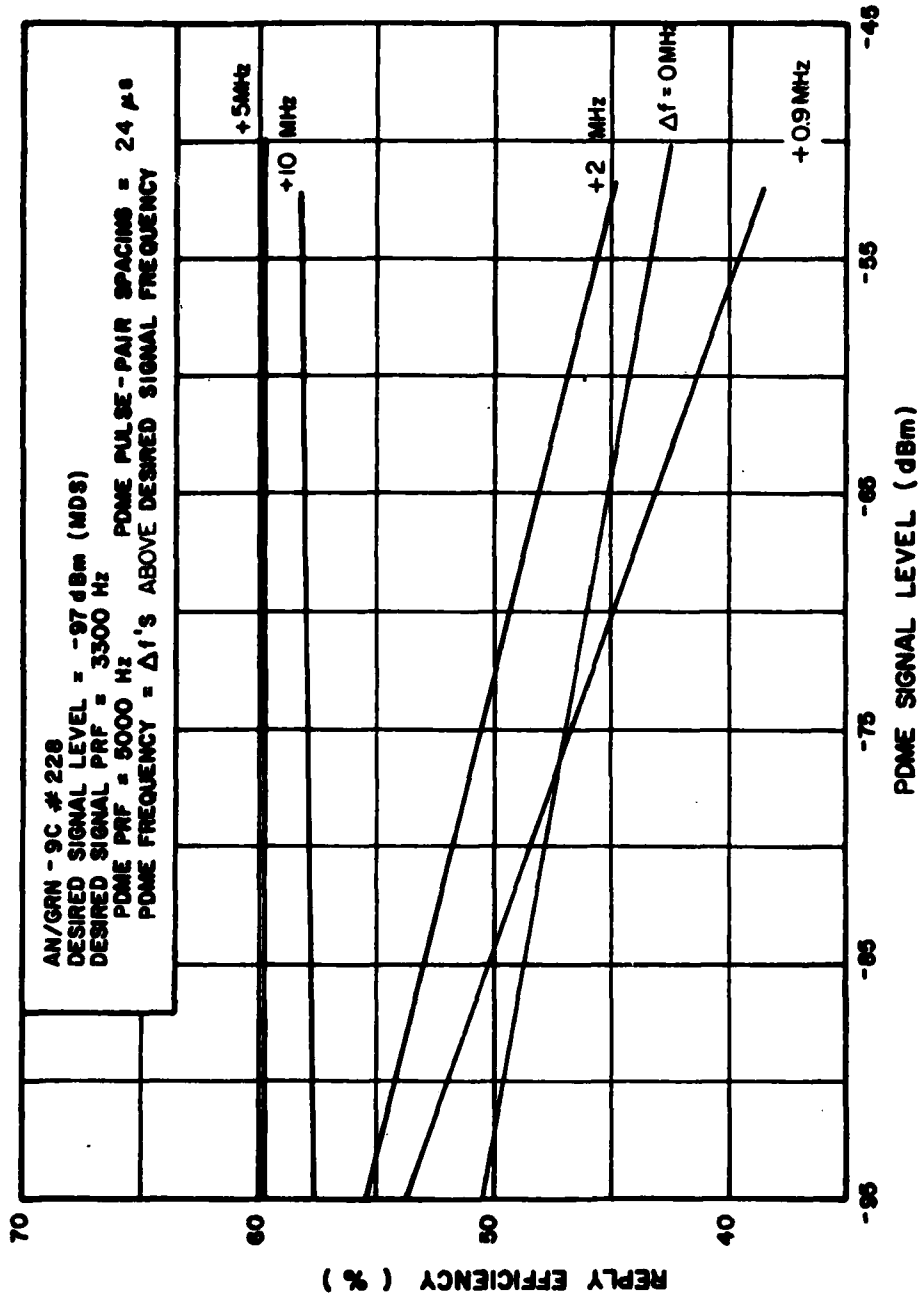


FIGURE 55. AN/GRN-9C PERFORMANCE WITH ADJACENT-CHANNEL INTERFERENCE WHEN DESIRED SIGNAL IS -97 dBm AND PDME Δf IS 0 TO +10 MHz.

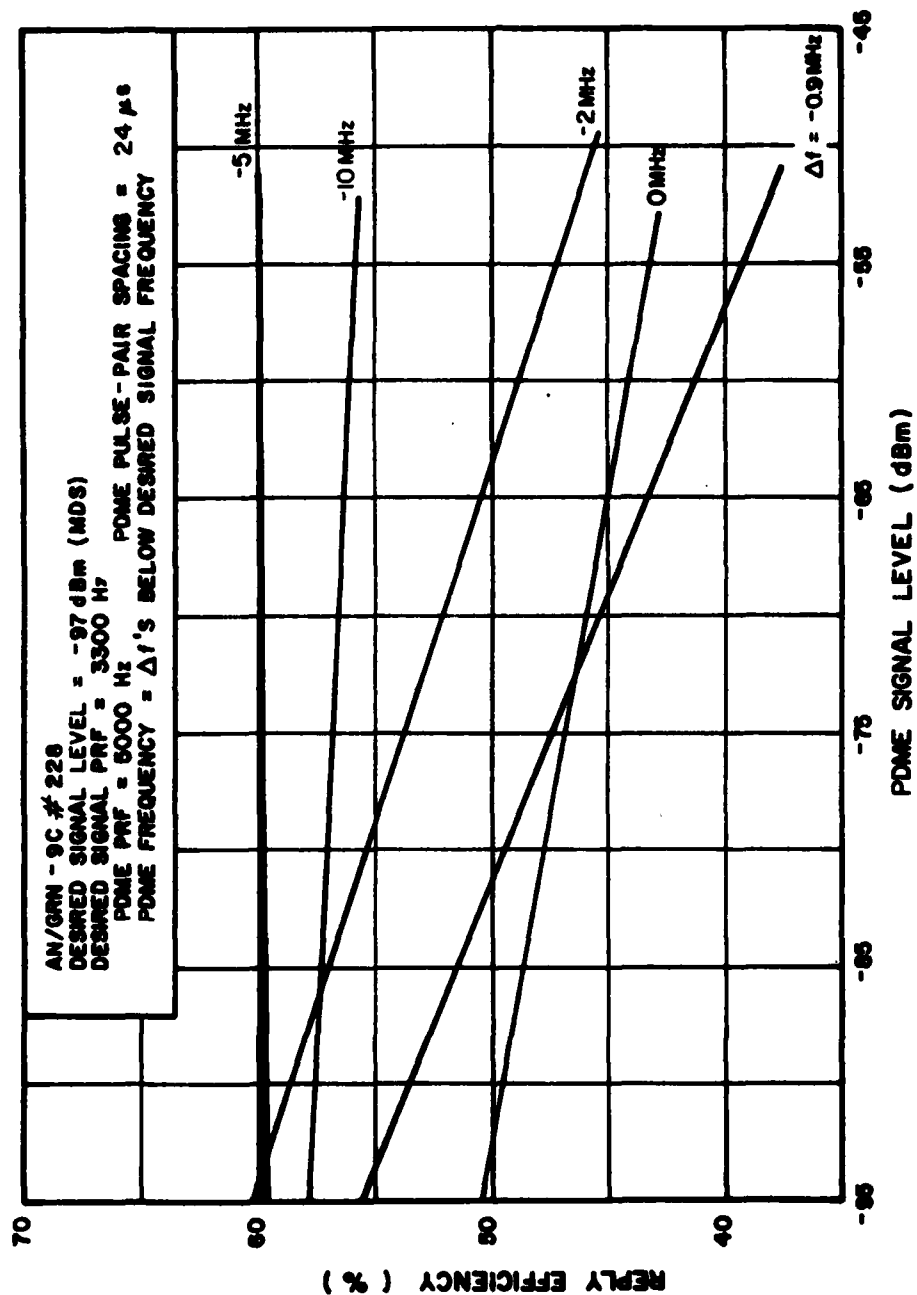


FIGURE 56. AN/GRN-9C PERFORMANCE WITH ADJACENT-CHANNEL INTERFERENCE WHEN DESIRED SIGNAL IS -97 dBm AND PDME Δf IS 0 TO -10 MHz.

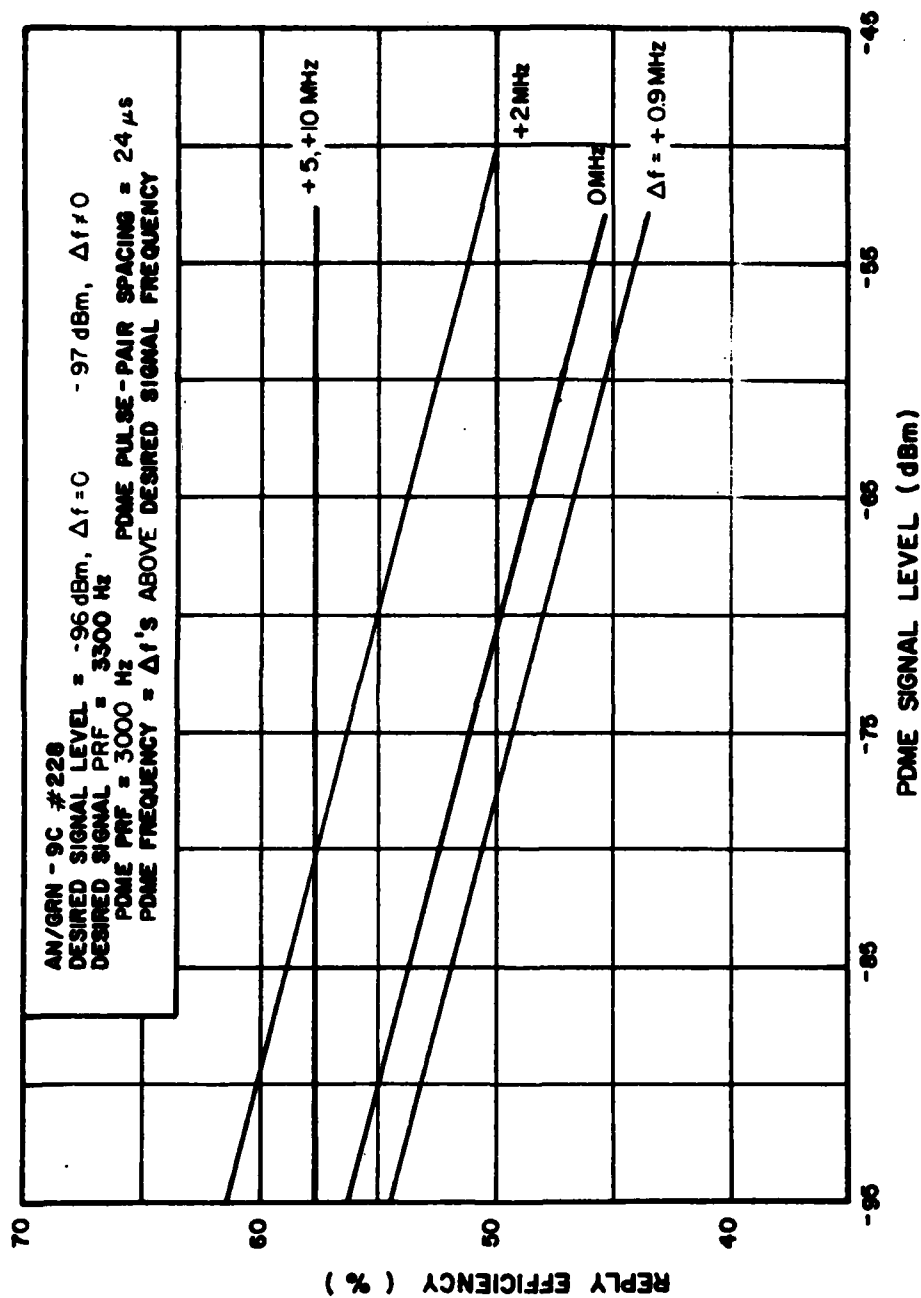


FIGURE 57. AN/GRN-9C PERFORMANCE WITH ADJACENT-CHANNEL INTERFERENCE WHEN DESIRED SIGNAL IS -96/-97 dBm AND PDME Δf IS 0 TO +10 MHz.

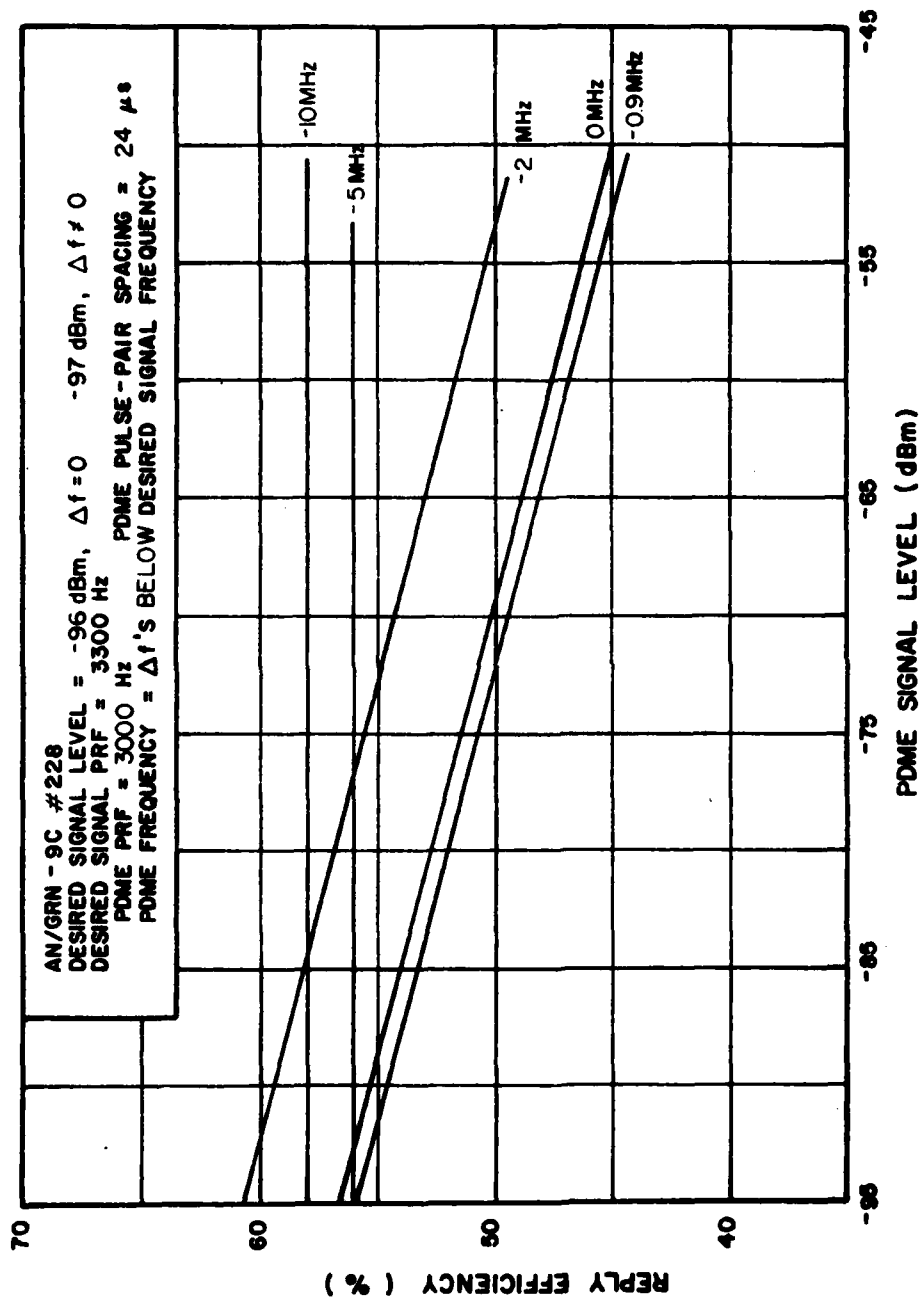


FIGURE 58. AN/GRN-9C PERFORMANCE WITH ADJACENT-CHANNEL INTERFERENCE WHEN DESIRED SIGNAL IS -96/-97 dBm AND PDME Δf IS 0 TO -10 MHz.

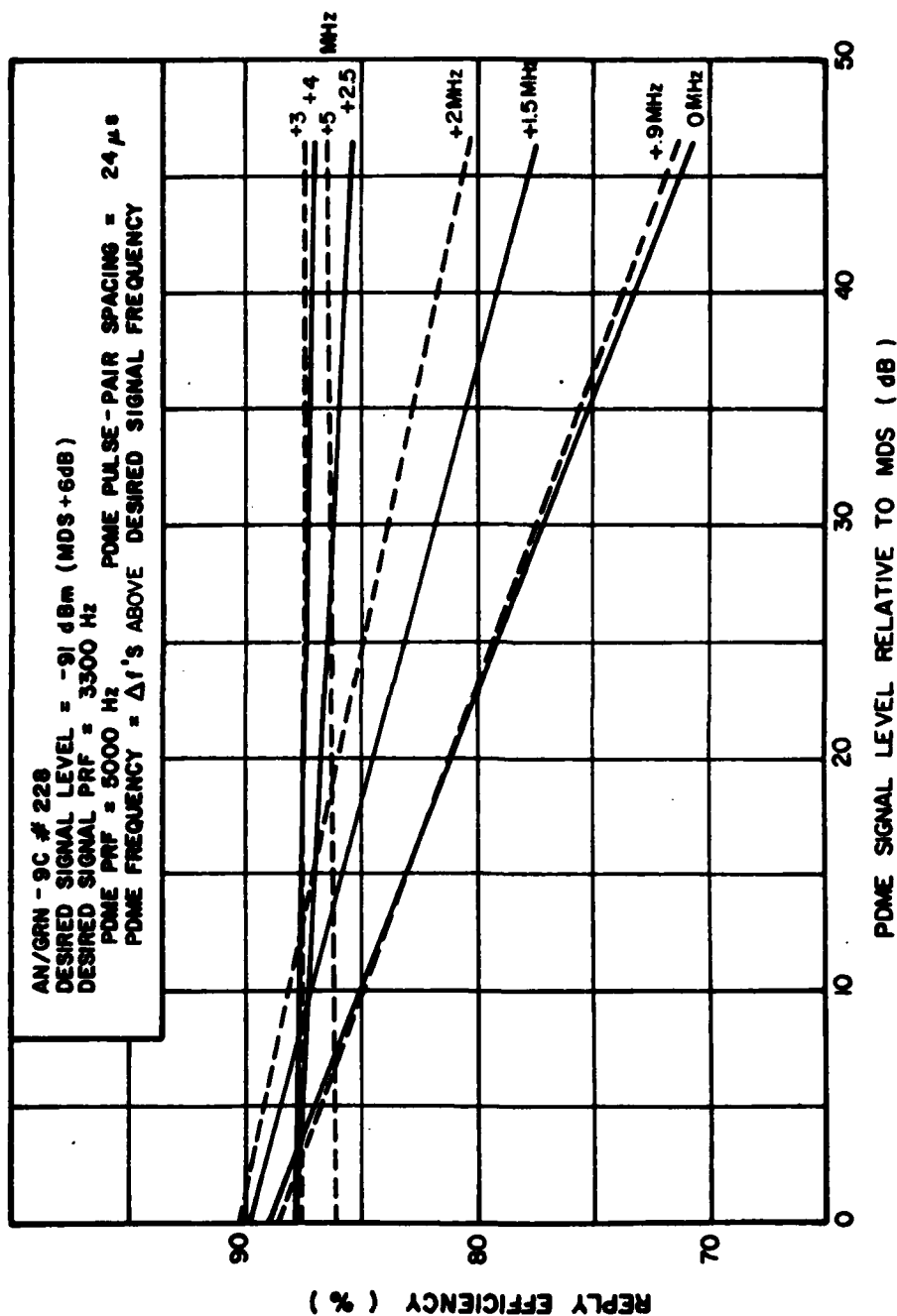


FIGURE 59. AN/GRN-9C PERFORMANCE WITH ADJACENT-CHANNEL INTERFERENCE WHEN DESIRED SIGNAL IS -91 dBm AND PDME Δf IS 0 TO +5 MHz.

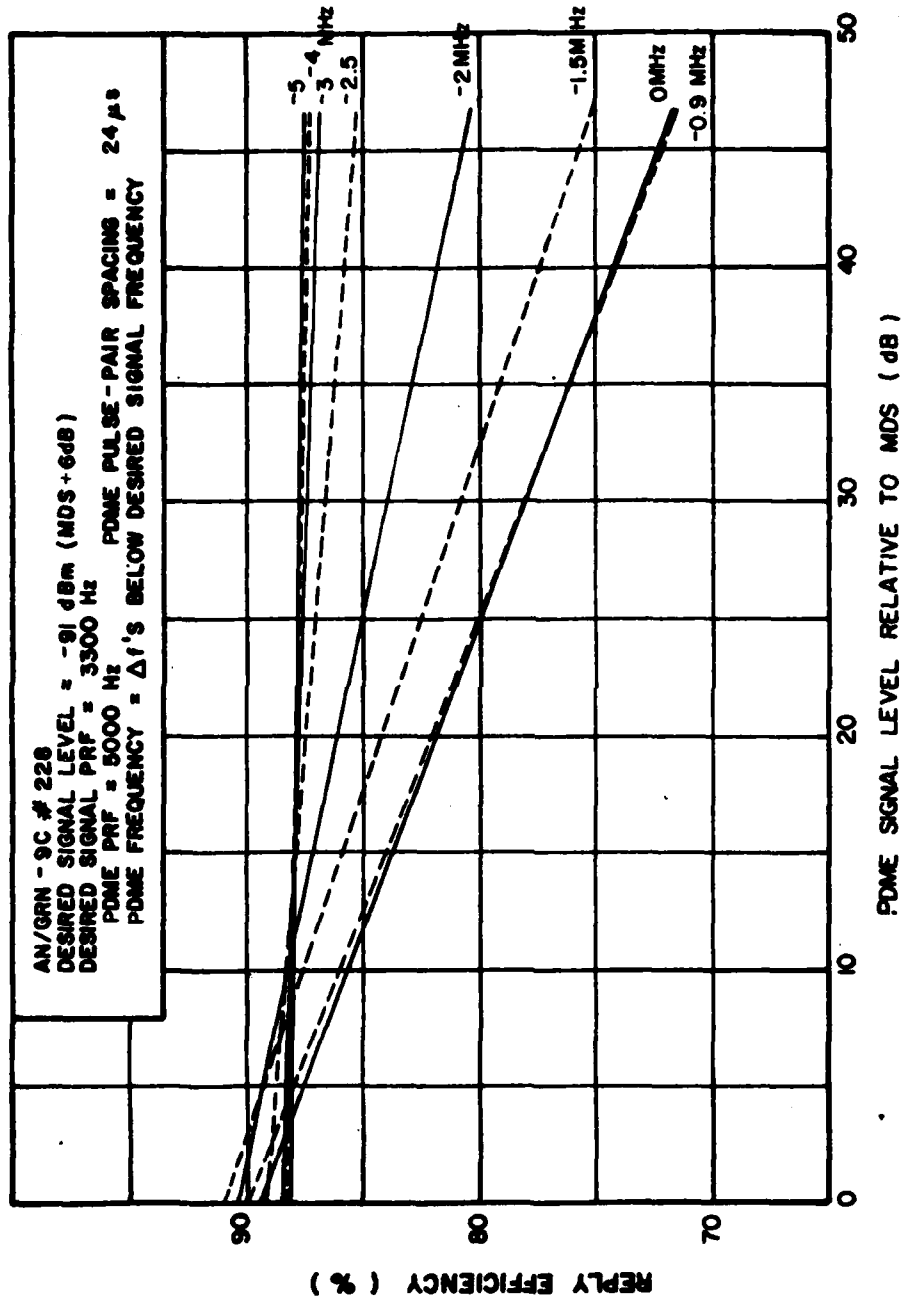


FIGURE 60. AN/GRN-9C PERFORMANCE WITH ADJACENT-CHANNEL INTERFERENCE WHEN DESIRED SIGNAL LEVEL IS -91 dBm AND PDME Δf IS 0 TO -5 MHz.

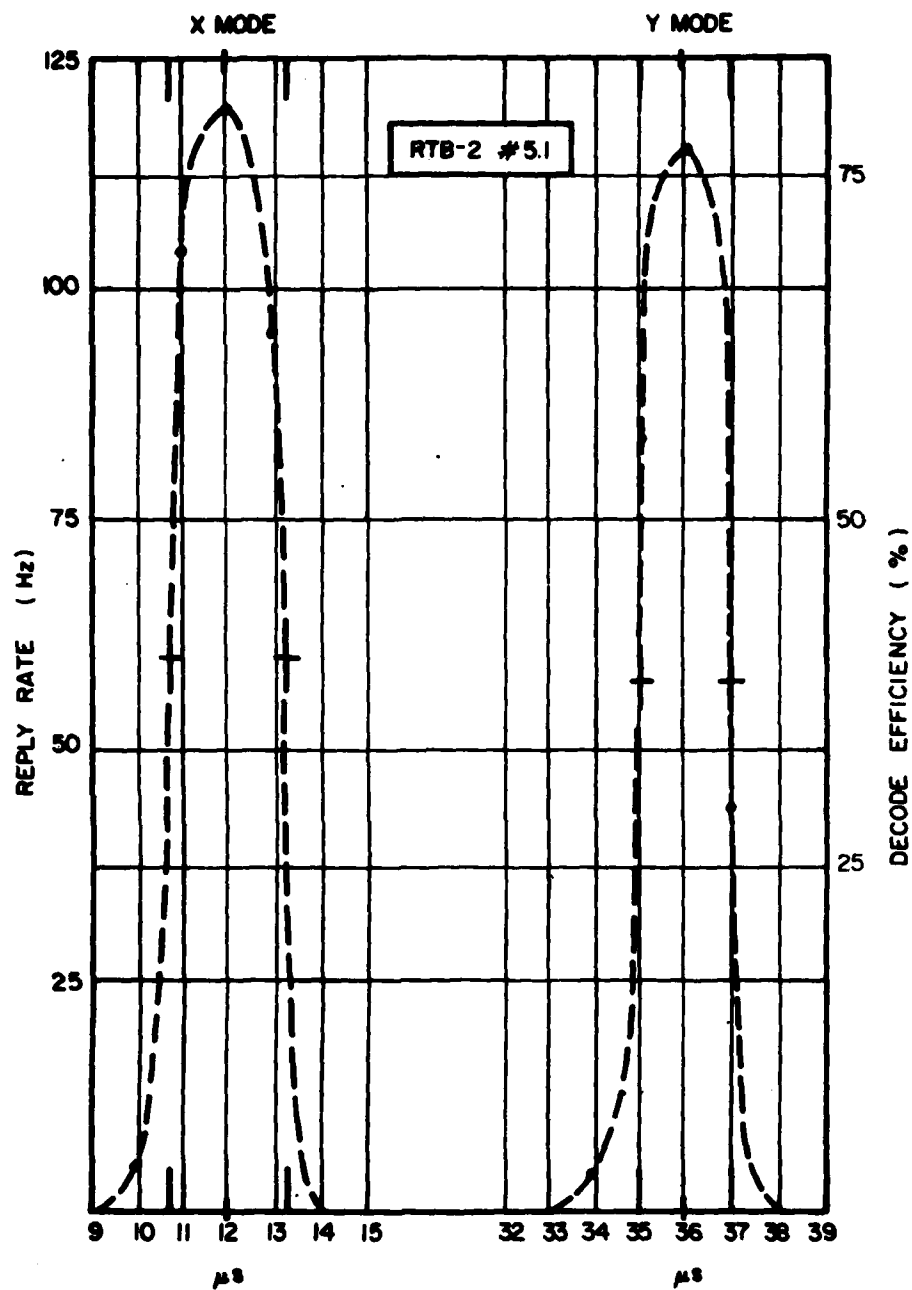


FIGURE 61. RTB-2 DECODER APERTURE BASED ON MEASUREMENTS USING PDME SIGNAL LEVELS OF -75, -85, -95 dBm AND A 150 PULSE-PAIR/SECOND TRANSMISSION RATE.

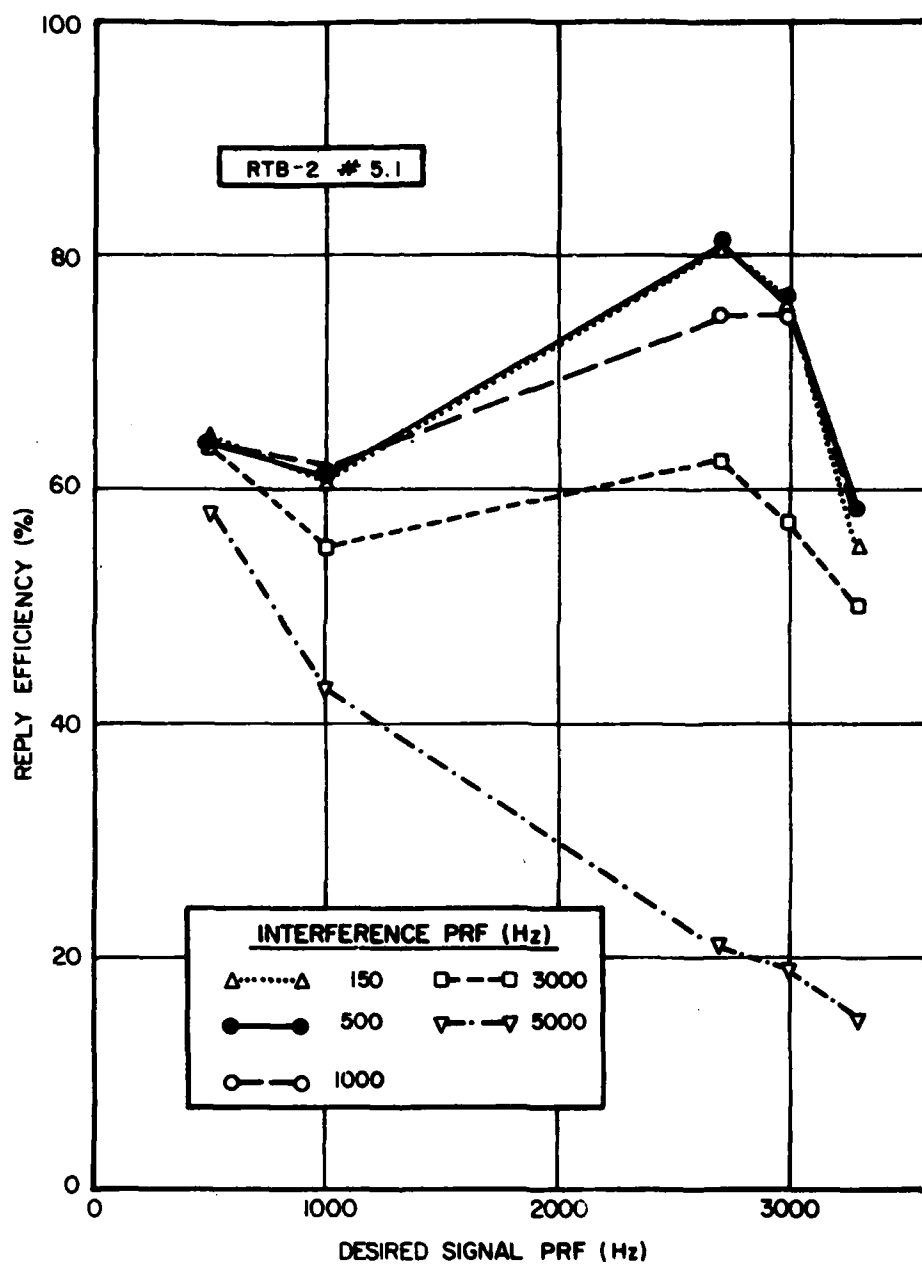


FIGURE 62. RTB-2 X-MODE REPLY EFFICIENCY WITH COCHANNEL INTERFERENCE AND DESIRED SIGNAL OF -95 dBm AND PDME PULSE SPACING OF 12 μ s.

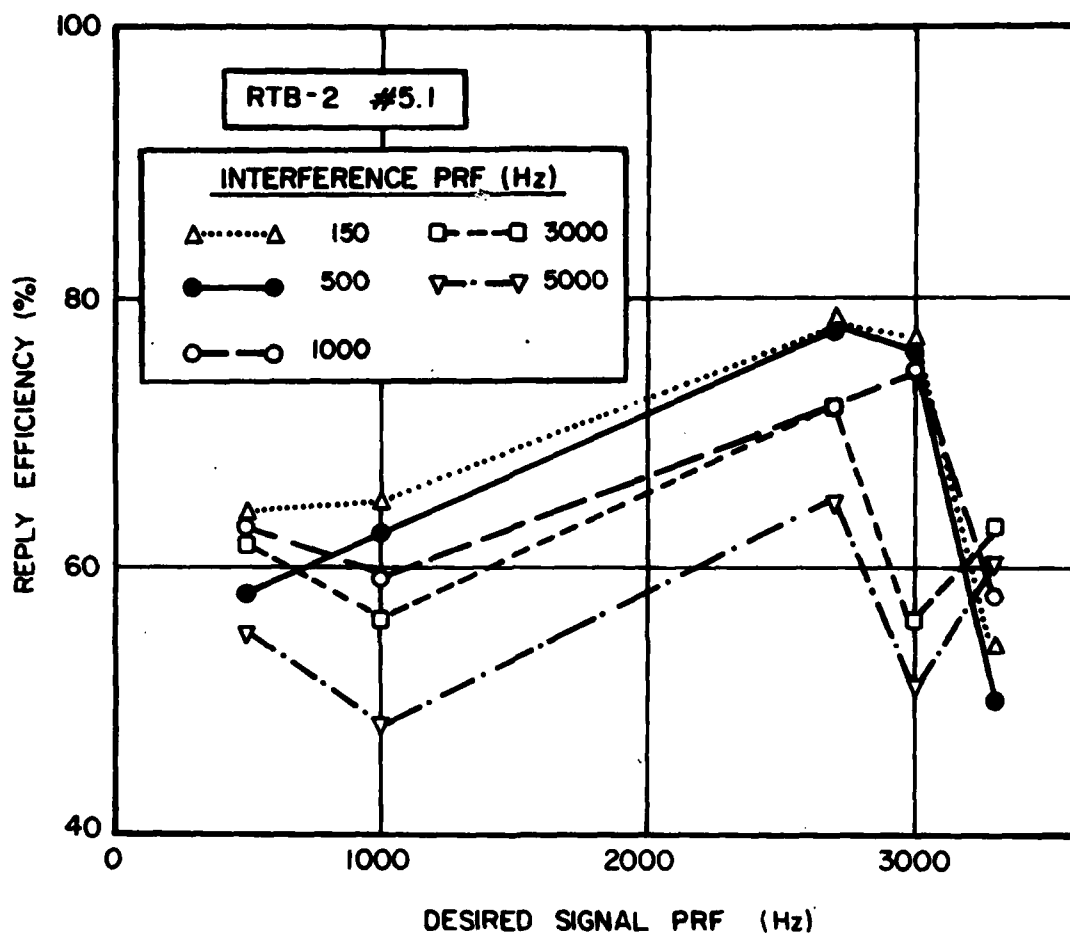


FIGURE 63. RTB-2 X-MODE REPLY EFFICIENCY WITH COCHANNEL INTERFERENCE AND DESIRED SIGNAL OF -95 dBm AND PDME PULSE SPACING OF 18 μ s.

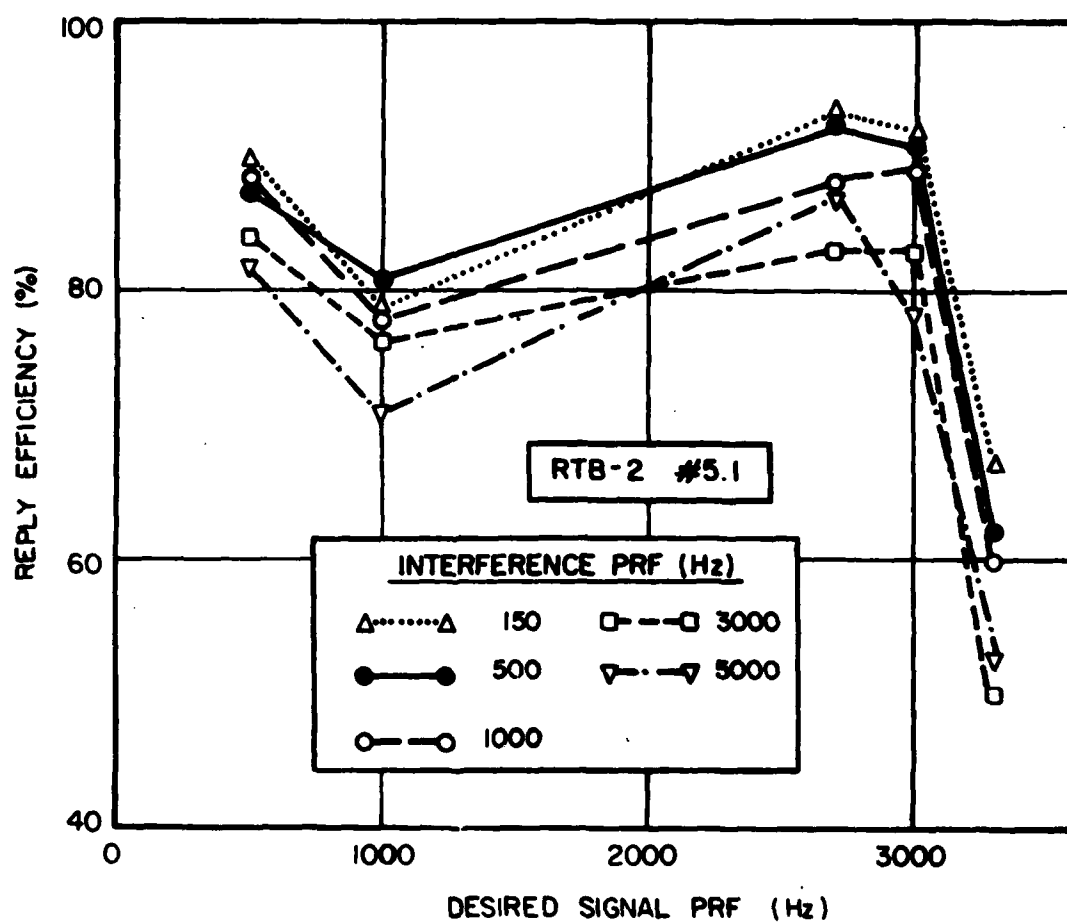


FIGURE 64. RTB-2 X-MODE REPLY EFFICIENCY WITH COCHANNEL INTERFERENCE AND DESIRED SIGNAL OF -89 dBm AND PDME PULSE SPACING OF 18 μ s.

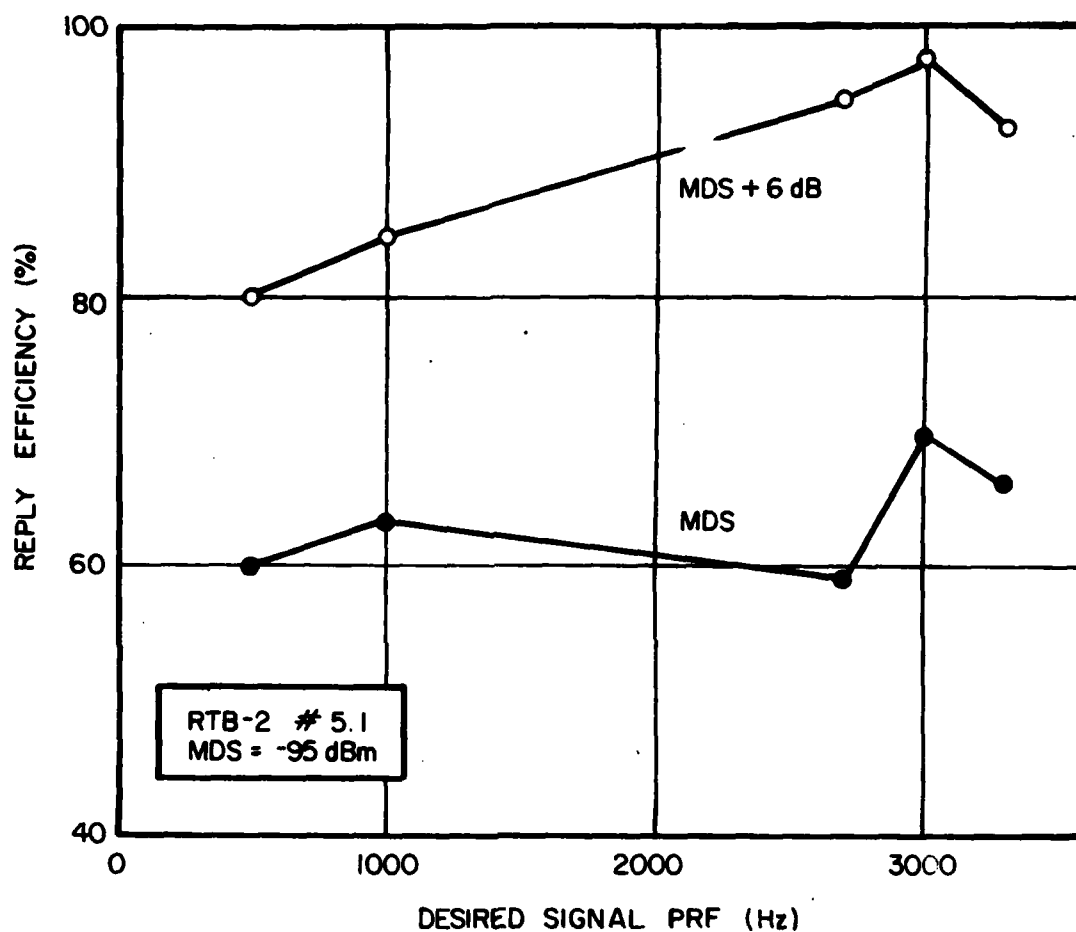


FIGURE 65. RTB-2 Y-MODE REPLY EFFICIENCY WITHOUT INTERFERENCE.

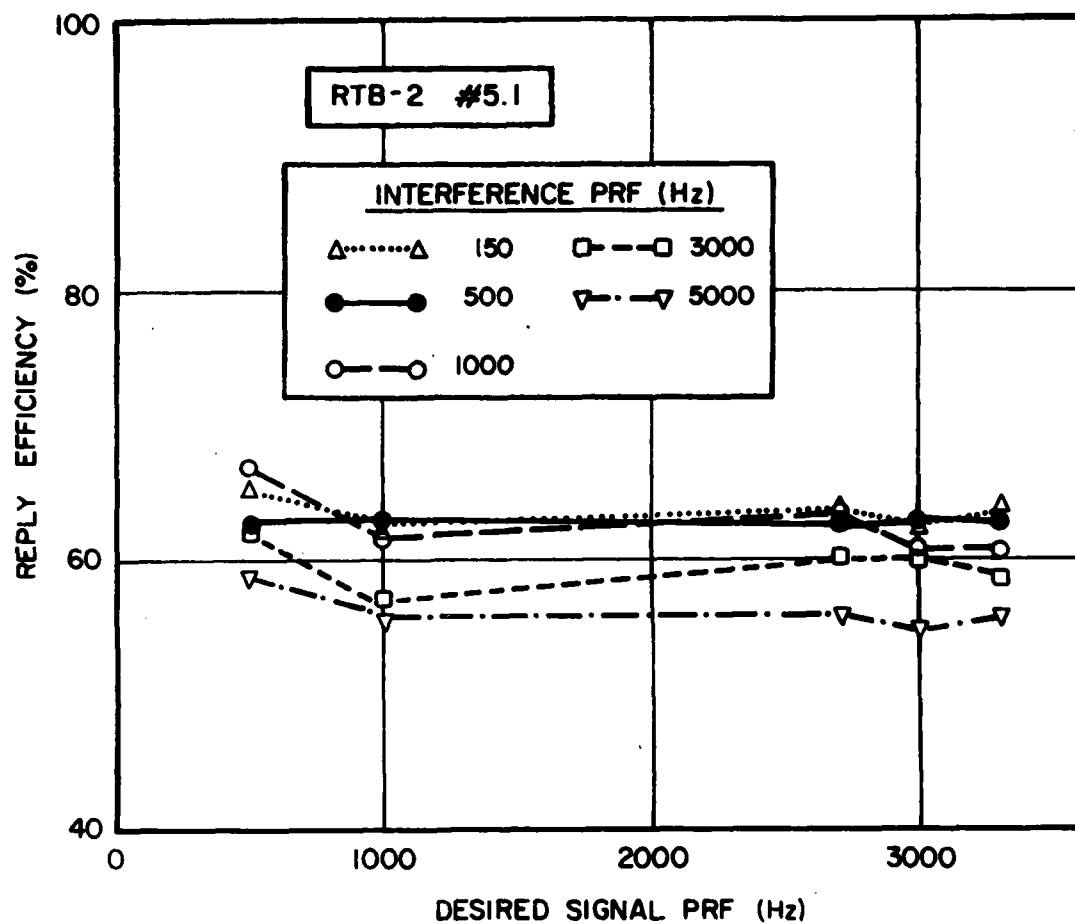


FIGURE 66. RTB-2 Y-MODE REPLY EFFICIENCY WITH COCHANNEL INTERFERENCE AND DESIRED SIGNAL OF -95 dBm AND PDME PULSE SPACING OF 42 μ s.

FIGURES 53 and 54 display transponder performance in the presence of decodable interference (12- μ s pulse-pairs). Once the interference becomes 0.9 MHz off-tune, the reply efficiency increases significantly. Continuing to increase the frequency separation does not produce a linear increase in efficiency. With no frequency separation, the interference is accepted by the Ferris discriminator and decoded. This accounts for the low reply efficiency, since the desired signal must compete with the interference for the decoder. At 0.9 MHz separation, the Ferris discriminator prevents acceptance of the interference and any degradation in reply efficiency is due solely to echo-suppression deadtime generated by the interference. FIGURE 54 shows that a separation of -10 MHz results in lower performance than if the separation is -5 Hz. This result may be erroneous.

For nondecodable interference (24 μ s) refer to FIGURES 55 and 56. Since the interference is not decodable, performance degradation that occurs with no frequency separation is a function only of the echo-suppression deadtime. Separating the desired and interfering signals by 0.9 MHz does not improve performance from its maximum of 53%.

FIGURE 43 illustrated that with no interference the reply efficiency was 60% for a desired signal at MDS. Increasing the frequency separation does not result in 60% reply efficiency until the separation is at least 5 MHz. This shows that frequency separation of 5-10 MHz between the desired TACAN/DME signal and the PDME interference is needed to obtain TACAN/DME performance equivalent to that with no interference present. This result holds also with a lesser interference rate of 300 Hz which compares to a fully loaded transponder or a large number of interrogators (see FIGURES 57 and 58). Comparing FIGURES 53 and 55 indicates that nondecodable signal formats do not provide any increased interference protection for the transponder over that of decodable signal formats when the interference is frequency-separated from the desired signal.

Raising the desired signal level by 6 dB does not change the above conclusions. FIGURES 59 and 60 show the adjacent-channel performance for nondecodable

interference when the desired signal is 6 dB above MDS. Comparing these figures with FIGURES 55 and 56 indicates that transponder performance with a strong desired signal in the presence of PDME interference remains unchanged except for an upward translation of the curves. Again, these figures indicate 5 MHz separation will maintain the reply efficiency at a level equivalent to the non-interference performance. Unfortunately, data is not available for the decodable interference in the presence of the strong desired signal, but it is believed that it would substantiate the conclusion that nondecodable and decodable PDME interference produce comparable changes in transponder performance when the TACAN/DME and PDME signals are frequency-separated.

Cochannel Results for the Modified RTB-2 Transponder. The modified RTB-2 transponder is an experimental model with features that may be incorporated in the next generation of TACAN ground stations. The differences between the modified and unmodified equipments are in the receiver, which makes extensive use of digital techniques for adjacent-channel discrimination, decoding, interpulse deadtime, echo-suppression deadtime, and delay timing. The system also has an increased capacity feature that permits the reply rate to increase to a maximum of 5000 Hz instead of the present 2700 Hz.

The transponder feature used as a parameter in the measurement program for PDME was the echo suppression. A valid decode causes a reduction in sensitivity for 50 to 400 μ s (depending on the blanking gate setting). The deadtime is adjustable, as is the maximum change in sensitivity and the rate of return to nominal sensitivity. The echo suppression will be triggered by valid interrogations arriving at signal levels above a predetermined level (either -70 or -80 dBm). For the measurements addressed in this report, deadtimes of 50, 250, and 400 μ s were considered, along with triggering levels of -70 and -80 dBm. Fifty microseconds corresponds to having no echo suppression, because the reply deadtime is longer. The other adjustments were set according to manufacturer's suggestions.

The decoder aperture of the RTB-2 in the X-mode extends from 10.7 to 13.3 μ s with peak sensitivity to spacings of about 11.8 μ s. No decodes occur outside the limits of 9 to 14 μ s (see FIGURE 61). In Y-mode operation the aperture is narrower (exactly 2 μ s) and symmetrical around the spacing 35.8 μ s. No pulse pairs outside the limits 33 to 38 μ s will be decoded. Thus, the aperture of the RTB-2 is approximately 2 μ s narrower than that of the AN/GRN-9C (see FIGURE 38).

FIGURE 62 shows typical X-mode behavior with a desired signal at MDS and decodable interference (12 μ s spacing). The data points represent a weighted average of performance with PDME signal levels ranging from -95 to -45 dBm. (The distribution used for weighting showed the majority of received signals between -90 and -70 dBm; therefore, readings taken with PDME levels of -85 and -75 dBm contribute most significantly to the averages used here.)

As expected, the decrease in reply efficiency is sharpest where the interfering PRF is 5000 Hz. When, in addition, the PRF of the desired signal is 3300 Hz, efficiency of 15% or less may be experienced. Furthermore, the interfering signal need be no stronger than -85 dBm (MDS + 10 dB) to produce this reduction. (This figure is not apparent from the graph due to the averaging of readings.)

When the interfering PRF is reduced, reply efficiency increases. For interference rates of 500 Hz or less, efficiency as high as 80% can be obtained. When the desired signal PRF exceeds 3000 Hz, however, a decrease in efficiency is observed. No explanation is offered for this behavior. It appears to be a characteristic of the equipment that only occurred in X-mode operation.

FIGURE 63 shows the behavior of the transponder when the interference is nondecodable (18 μ s spacing), all other parameters being the same as in FIGURE 62. Here the decrease in reply efficiency with increasing interference PRF occurs under the same conditions, but not to the same extent, as in the previous case. When the interference rate is 5000 Hz, the reduction in reply efficiency

is on the order of 15% compared to the level obtained with little interference. Notice that the graphs of FIGURE 63 show a close similarity with one another. Reply efficiency increases or decreases in a fairly consistent pattern independent of the interference rate. The previously mentioned dip in reply efficiency for desired PRF's greater than 3000 Hz occurs here also, and the unexpected and unexplained rise in efficiency of the two lowest curves is not typical of all the data observed.

FIGURE 64 shows transponder behavior with the desired signal increased to 6 dB above MDS and nondecodable interference. Comparison of this figure with the previous one shows expected similarities, namely the congruence of the curves and the drop in reply efficiency at the highest desired-signal PRF. The differences between the figures shows that a stronger desired signal produces both a higher overall efficiency and a smaller differential in efficiency (10% instead of 15%) between the curves for 150 and 5000 Hz PDME interference.

All of the previous graphs represent data taken with an echo-suppression deadtime of 250 μ s and a triggering level of -70 dBm. It was assumed that varying these parameters would produce some changes in the observed levels of reply efficiency. For example, using a deadtime of 400 μ s should produce lower efficiencies, as more deadtime causes more decodable signals to be inhibited, especially at high desired and interference rates. In fact, no apparent effect was produced by varying either deadtime or triggering level.

The efficiency of the transponder operating in the Y-mode without interference is shown in FIGURE 65. MDS is defined as the desired signal level that produces 60% efficiency, which is achieved here at -95 dBm. At MDS + 6 dB (-89 dBm) the efficiency increases smoothly from 80% to almost unity before dropping off. Comparing these curves with the behavior of the AN/GRN-9C without interference (FIGURES 51 and 52) shows very similar characteristic behavior.

FIGURE 66 represents a Y-mode desired signal at MDS with nondecodable interference (42 μ s interference pulse spacing). Comparison with the interference-free

case shows the best efficiency remains at or slightly above 60%, while in the presence of 5000 Hz interference the reduction in efficiency is at most 8%. All the graphs are flat and show a high degree of congruence to one another. (The equivalent data for X-mode was shown in FIGURE 63.)

Raising the desired signal to MDS + 6 dB produces the data shown in FIGURE 67. The overall efficiency is lower than would be expected from a comparison with FIGURE 65. However, the graphs do exhibit a higher reply efficiency than shown for the case where the desired signal is at MDS. The curves for Y-mode operation show the same congruence as those for X-mode performance.

The data so far presented for the RTB-2 is very similar to that shown for the AN/GRN-9C. FIGURES 52, 64, and 67 show the composite performance of both transponders as a function of PDME interference having nondecodable pulse-pairs. Comparing X-mode performance of both equipments (FIGURES 52 and 64) it can be seen that performance is nearly identical, with the RTB-2 being slightly less susceptible to the higher interference rates of 3000 and 5000 Hz. Comparing FIGURES 52 and 64 with FIGURE 67 shows that, although the overall reply efficiency in Y-mode never exceeded 80%, the RTB-2 in Y-mode operation was less sensitive to the PDME interference. Since the Y-mode performance data differs greatly from the RTB-2 X-mode data, both sets of data may be in question. However, for cochannel interference, there appears to be no significant difference in AN/GRN-9C or modified RTB-2 performance in the presence of PDME interference. The improved design of the experimental equipment may enhance TACAN/DME range accuracy and system reliability but it, apparently, does not significantly enhance performance in the presence of interference as compared with operational TACAN equipment.

Adjacent-Channel Results for the Modified RTB-2 Transponder. FIGURES 68 through 71 show the effect on transponder reply efficiency due to nondecodable interference at frequencies up to 5 MHz away from that of the transponder. Each

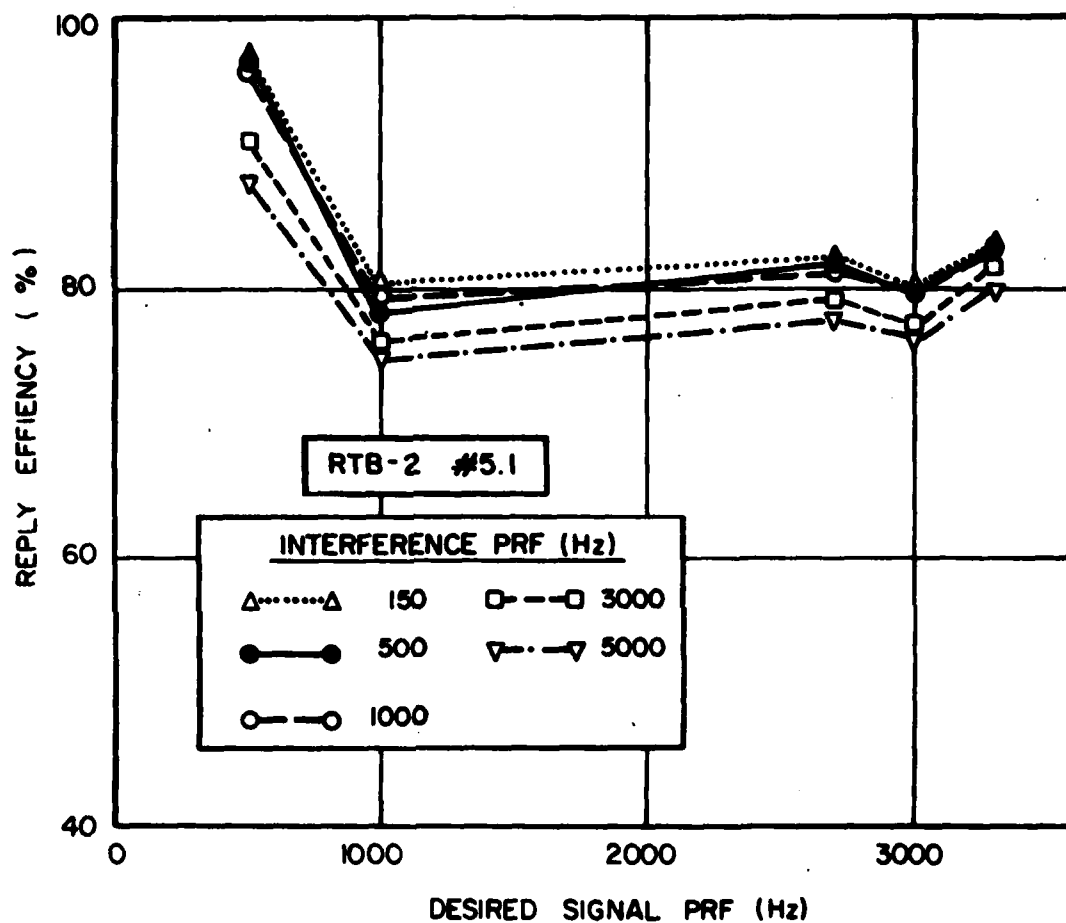


FIGURE 67. RTB-2 Y-MODE REPLY EFFICIENCY WITH COCHANNEL INTERFERENCE AND DESIRED SIGNAL OF -89 dBm AND PDME PULSE SPACING OF 42 μ s.

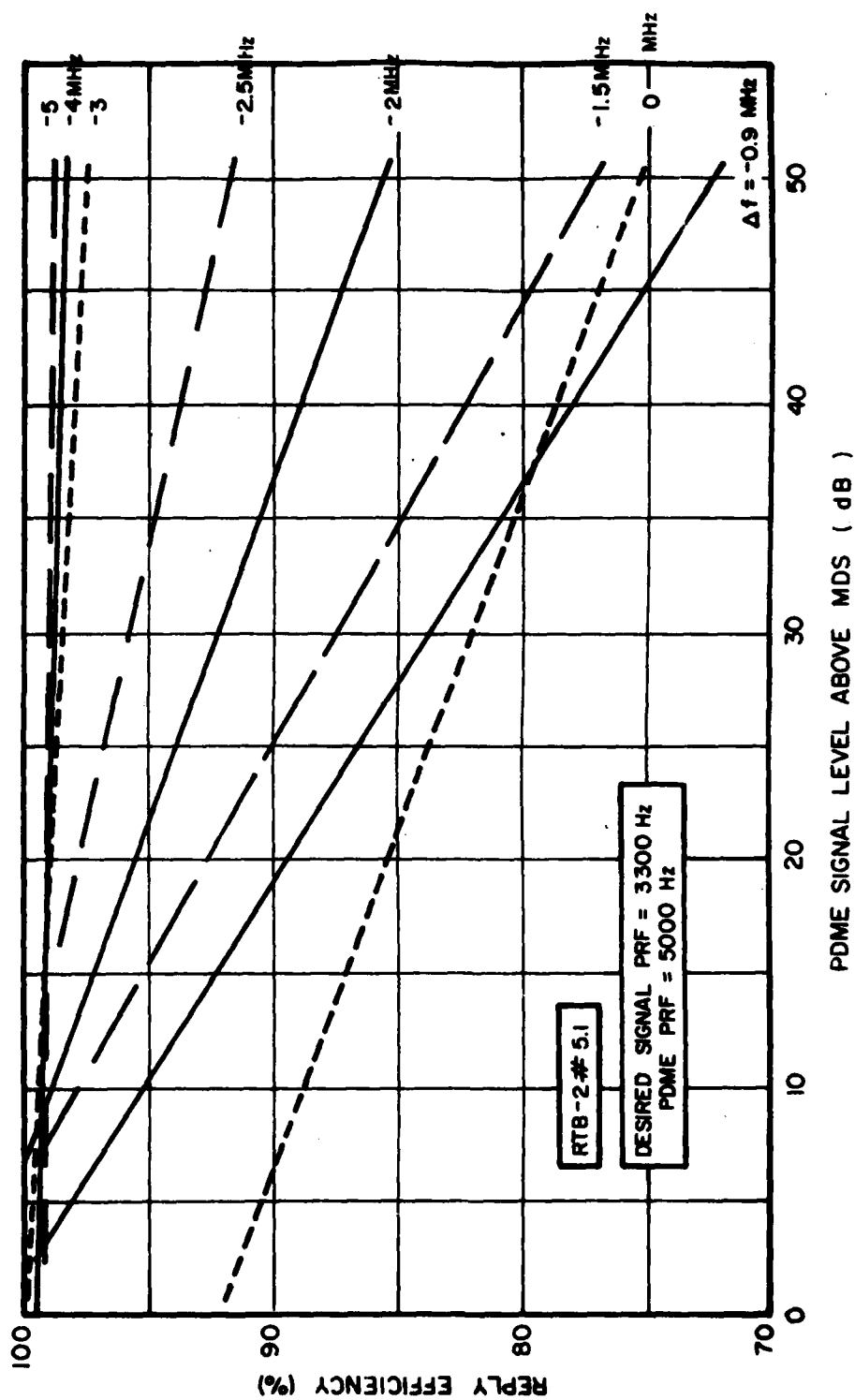


FIGURE 68. RTB-2 REPLY EFFICIENCY WITH ADJACENT-CHANNEL INTERFERENCE, X-MODE, DESIRED SIGNAL OF -89 dBm, PDME PULSE SPACING OF 18 μ s, AND PDME BELOW RTB-2 FREQUENCY.

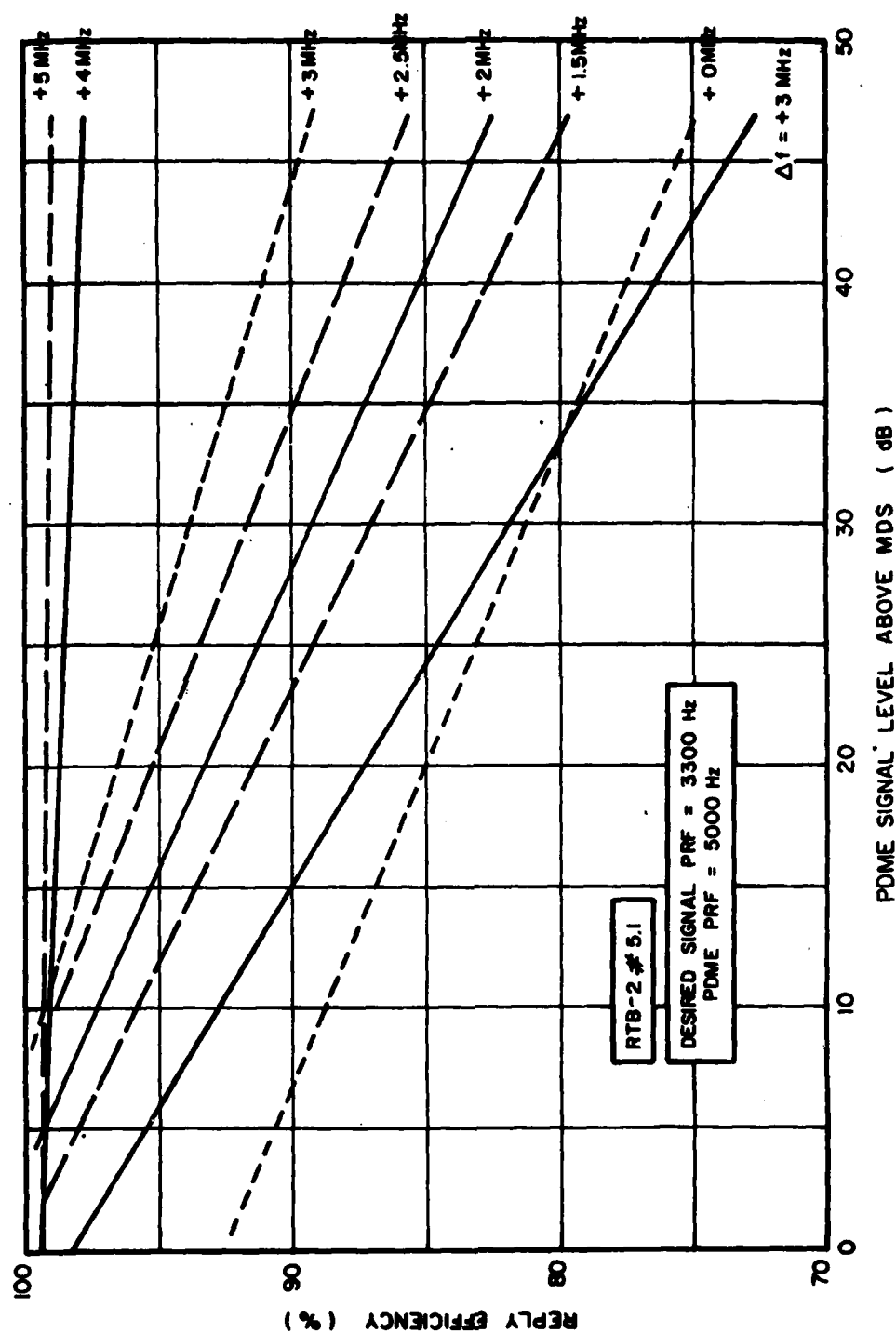


FIGURE 69. RTB-2 REPLY EFFICIENCY WITH ADJACENT-CHANNEL INTERFERENCE, X-MODE, DESIRED SIGNAL LEVEL OF -89 dBm, PDME PULSE SPACING OF 18 μ s, AND PDME ABOVE RTB-2 FREQUENCY.

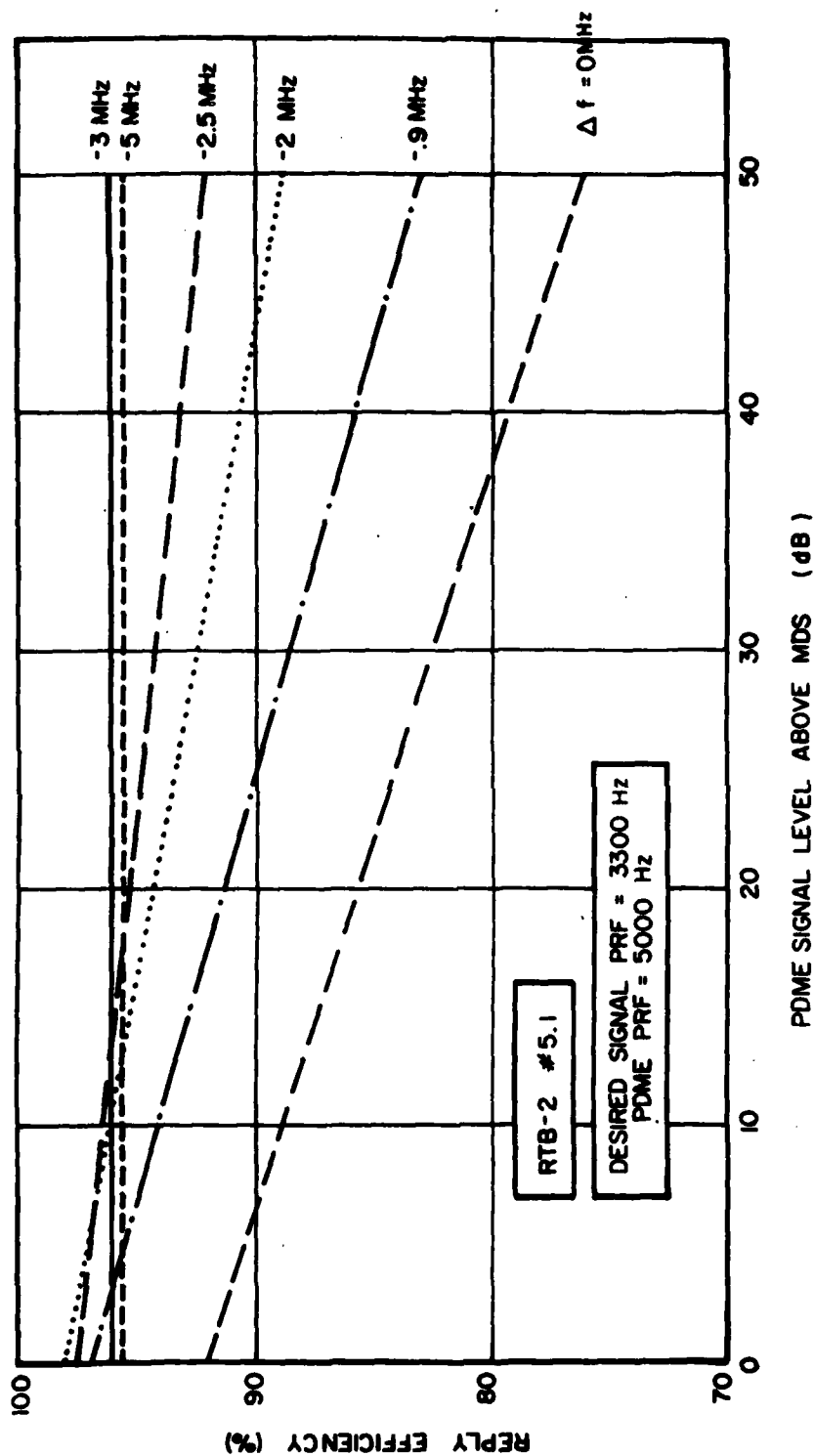


FIGURE 70. RTB-2 REPLY EFFICIENCY WITH ADJACENT-CHANNEL INTERFERENCE, Y-MODE, DESIRED SIGNAL LEVEL OF -89 dBm, PDME PULSE SPACING OF 42 μ s, AND PDME BELOW RTB-2 FREQUENCY.

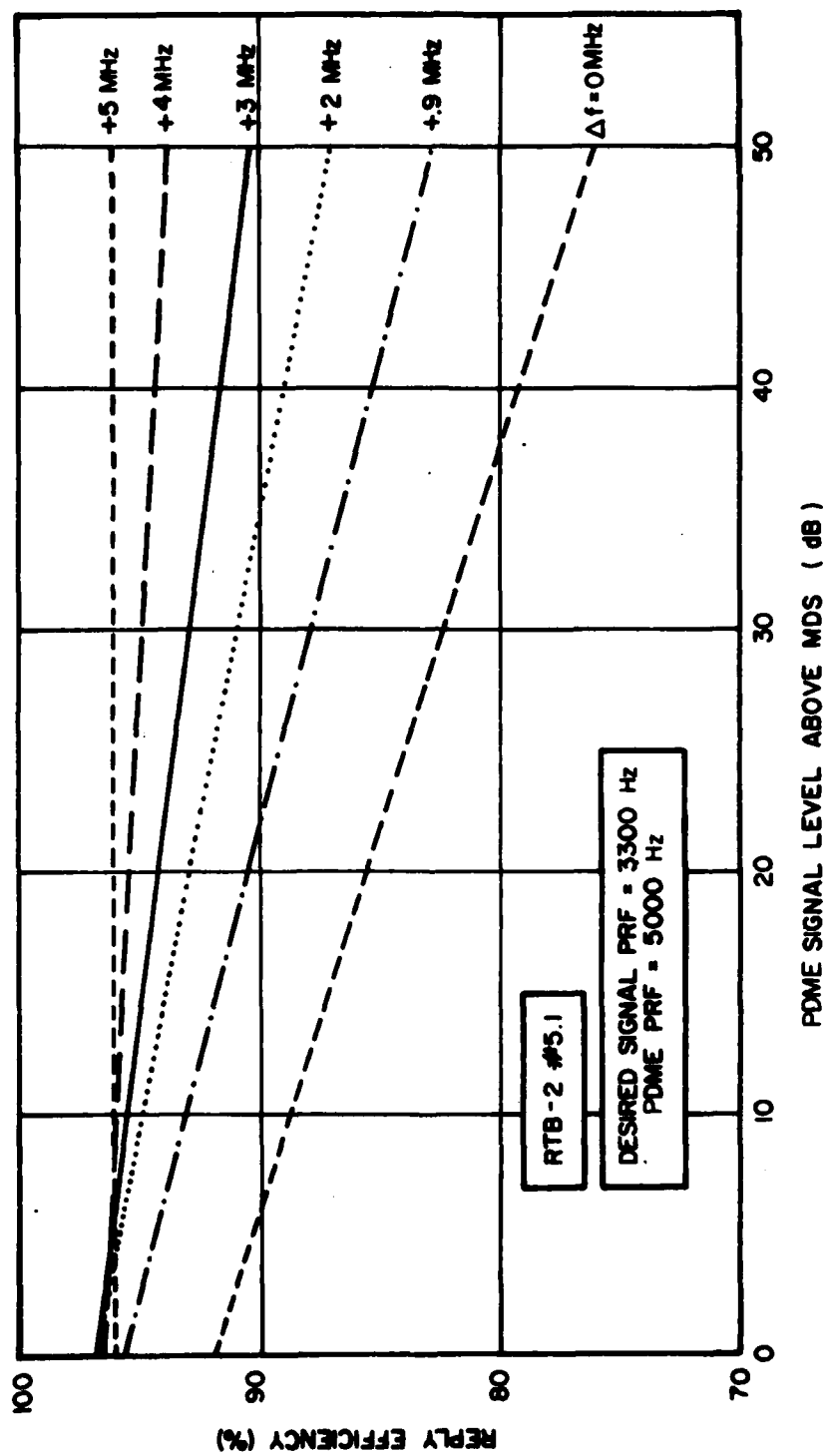


FIGURE 71. RTB-2 REPLY EFFICIENCY WITH ADJACENT-CHANNEL INTERFERENCE, Y-MODE, DESIRED SIGNAL LEVEL OF -89 dBm, PDME PULSE SPACING OF 42 μ s, AND PDME ABOVE RTB-2 FREQUENCY.

of the graphs represents a trend line that indicates the change in efficiency as the respective PDME signal increases from -95 to -45 dBm for a specific frequency separation.

FIGURE 68 represents X-mode performance with PDME signals below the RTB-2 frequency. The desired signal is at MDS + 6 dB (-89 dBm). From this figure the following may be observed:

1. Freedom from interference is obtained when the PDME signal frequency is 3 MHz below the transponder frequency.
2. As the PDME signal level increases, efficiency decreases faster at 900 kHz separation than for the on-tune (cochannel) case.

FIGURE 69 shows the corresponding data with PDME signals above the transponder frequency. FIGURES 70 and 71 show the same measurements for the Y-mode. Examining these graphs and comparing them with FIGURE 67 reveals that observation 1 alone is true in the Y-mode as well as X, but not true when the PDME signal frequency is above the RTB-2 channel frequency. An interference-free situation was not reached with less than 5 MHz separation when the interference was above the transponder frequency. This asymmetry in the adjacent-channel performance was observed in most of the data taken in these tests, and is probably a characteristic of the receiver IF circuitry. Complete interference-free operation would therefore seem to require 5 MHz separation on both sides of the transponder frequency. Note that this was also true for the AN/GRN-9C.

Observation 2, on the other hand, proved to be generally true of the X-mode results, but not Y-mode results. While the relative difference in reply efficiency for the two modes in the on-tune case were consistent with those obtained in the cochannel interference tests, the minimum levels for the 900-kHz case were usually about 10% lower in X-mode than in Y-mode. Comparison of FIGURE 68 with FIGURE 70, for example, will show this to be true *even though* the X-mode has higher efficiency in the interference-free case. The inconsistency is apparently due to a small

aberration in the selectivity curve of the Ferris discriminator. Situations in which a strong PDME signal is present, and separated from the transponder by less than 1 MHz, could therefore result in worse performance than with on-tune interference.

It should be emphasized that *the graphs shown are trend lines*. Since data points were taken at every 5 dB of PDME signal strength, attempting to plot point-to-point graphs would have made it impossible to include so many graphs in one illustration without confusion. However, one aspect that is not made evident is that the data points tend to follow not one, but two linear trends. This can be seen from FIGURE 72, which shows representative Y-mode results. Efficiency decreases only slightly until a certain interference level is reached, then it breaks sharply downward. Furthermore, the greater the frequency separation, the higher the level needed to cause this break. For example, from FIGURE 72 one could conclude that interference-free operation is possible at 1.5-MHz separation, so long as the PDME level does not exceed 15 dB above MDS. The actual figure, however, is 25 dB for 2 MHz separation, 35 dB for 2.5 MHz, and at 3 MHz the transponder is unaffected by any level of interference.

Varying other parameters has the following effects on the data and graphs:

1. Reducing the desired signal to MDS translates the graphs downward so that maximum efficiency is between 60 and 65%; other relationships remain unchanged.
2. Using decodable interference causes the on-tune efficiency to be greatly reduced--to 30% or less with maximum PDME level--but produces no significant change in the remaining data, even for the 900-kHz case, because of the selectivity of the Ferris discriminator.
3. Varying the deadtime or triggering level produces no appreciable effect.

Comparison of this data with that obtained for the AN/GRN-9C (FIGURES 53 through 60) reveals strikingly similar performance between the two transponders under all conditions discussed here.

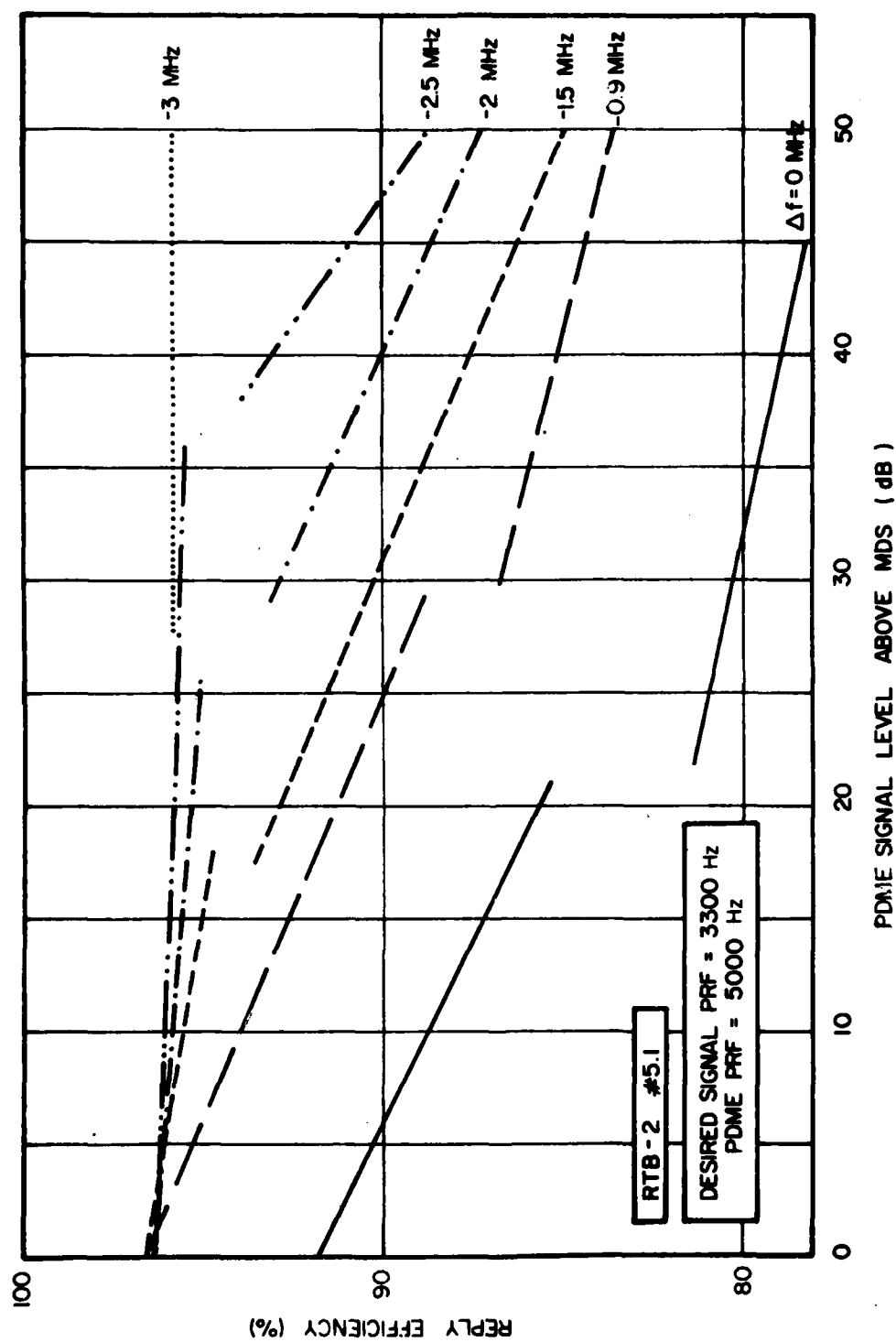


FIGURE 72. RTB-2 REPLY EFFICIENCY WITH ADJACENT-CHANNEL INTERFERENCE, Y-MODE, DESIRED SIGNAL LEVEL OF -89 dBm, PDME PULSE SPACING OF 42 μ s, AND MLS BELOW RTB-2 FREQUENCY.

Another method of confirming the selectivity of the Ferris discriminator is shown in FIGURE 73. This graph indicates the level of interfering signal that results in a constant synchronous reply rate (2700 Hz) at various frequency separations; i.e., the off-frequency rejection characteristics of the transponder. As expected when the interference is cochannel, a nondecodable PDME signal must be 8 dB stronger (compared to a decodable interfering signal) to reduce the desired reply rate to 2700 Hz. However, once the interfering signal is detuned far enough to prevent the discriminator from demodulating it (in this case 900 kHz is sufficient), the signal levels required to maintain the output rate are similar in both the decodable and nondecodable cases.

As a general observation, the foregoing measurements indicate that while the modified RTB-2 represents state-of-the-art equipment with more reliable and sophisticated design than that of the AN/GRN-9C, its performance in the presence of interfering PDME signals shows no significant improvement over that of the older transponder.

Physical Transponder Characteristics

Most models of the AN/GRN-9C currently in use as TACAN installations incorporate several field modifications, most notably a retriggerable blanking gate, which did not appear in the model used by NAFEC for these tests. On the other hand, the modified RTB-2 used by NAFEC contained an EDMAC Associates solid-state receiver with features not found in presently installed transponders. Thus, the test results cannot be presumed to be truly representative of the field performance of these equipments. In particular, the precise effects of the blanking gate or of its absence are uncertain.

Moreover, while susceptibility of the modified RTB-2 to interfering PDME signals was expected to be measurably better than that of the AN/GRN-9C due to the improved design of the receiver, the test data did not bear out this expectation.

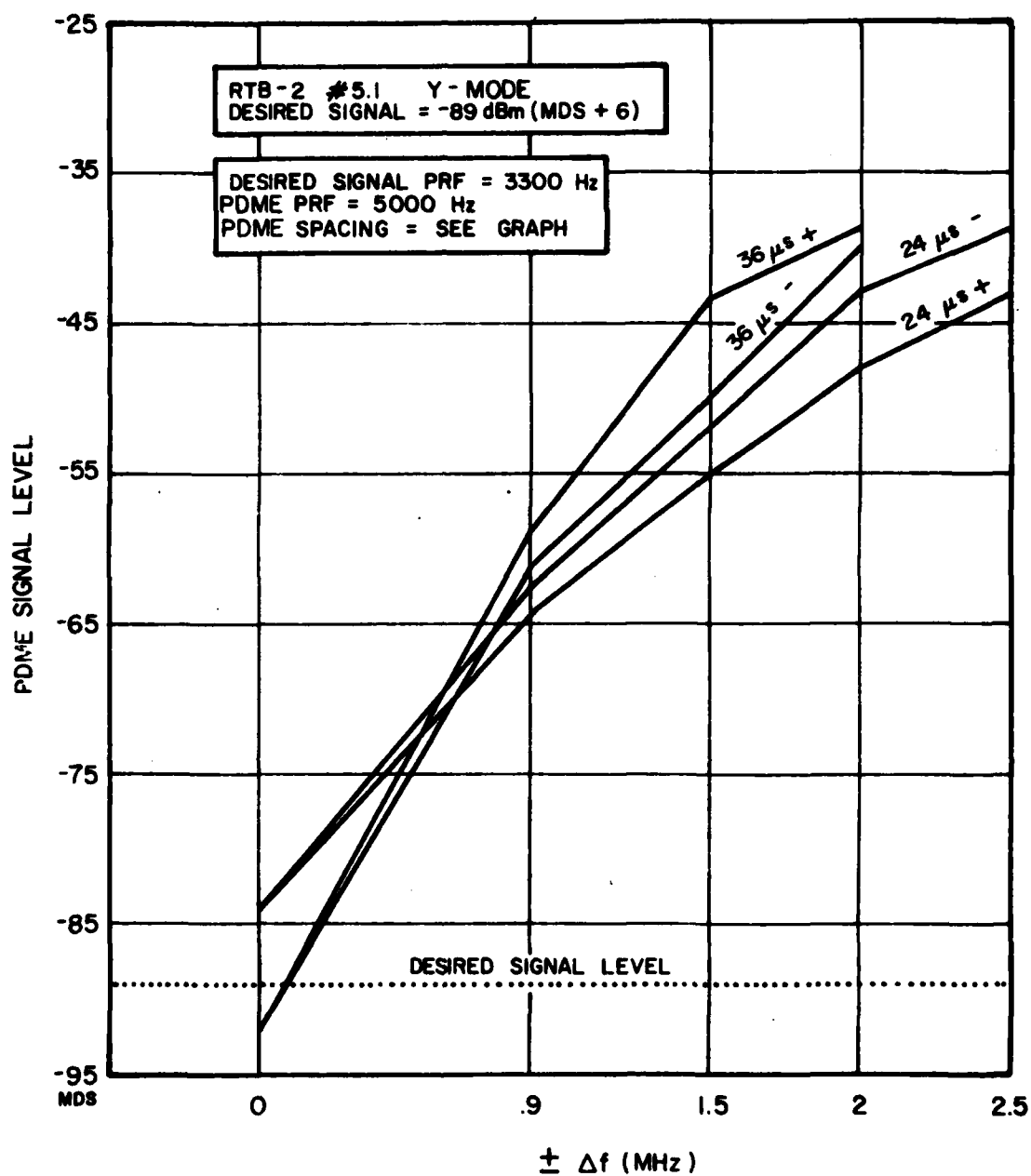


FIGURE 73. LEVEL OF INTERFERING SIGNAL FOR A CONSTANT SYNCHRONOUS REPLY RATE OF 2700 Hz AT DIFFERENT FREQUENCY SEPARATIONS.

Effects of PDME on Transponders

The National Standard on the VORTAC System (Reference 10) does not specify the performance of transponders in the presence of intrasystem interference, as it does for interrogators. The service provided by a TACAN ground station depends on its reply efficiency. Reference 10 specifies an MDS based on 70% reply efficiency, but for this measurement program, NAPEC set MDS with an efficiency of 60%. Many TACAN interrogators are capable of acquiring range or azimuth data from ground stations operating at an even lower reply efficiency.

If it were desired that a D/U interference protection criterion be determined for PDME transponders, it might be based on the national standard of 70% or on the 60% required by present TACAN maintenance standards. However, several factors prohibit obtaining a criterion from the measured data.

Four characteristics of the PDME signal produced degraded performance (i.e., less than 60% reply efficiency) in the AN/GRN-9C: signal strength (MDS + 20 dB or greater); high pulse-pair rate (3000 pp/s or more); decodability (12- μ s spacing); and adjacent-frequency spacing (\leq 2 MHz, including cochannel). The latter two might be termed controllable because proper channel and mode assignments can reduce their incidence; the first two are uncontrollable. The presence of any two of these undesirable characteristics was in most cases sufficient to prevent the transponder from attaining 60% reply efficiency with a desired signal at MDS. This was particularly true if one of the characteristics was adjacent-frequency spacing. The amount of test data obtained with only one undesirable characteristic present is not sufficient to determine any interference protection criterion.

While the RTB-2 did not exhibit as much susceptibility to moderate PDME interference as the AN/GRN-9C, determination of a D/U interference protection criterion is in this case hindered by the inconsistency of the data. For 60% reply efficiency, a worst-case D/U ratio of +2 dB was obtained in several tests,

yet under very similar test conditions ratios of -35 to -40 dB were also observed. Furthermore, the questionable reliability of the Y-mode results (see discussion in the following section) rendered half the test data effectively useless for making an absolute determination. Finally, regarding the four previously noted characteristics of the PDME signal which affected TACAN performance, no single characteristic or combination of two was found that had as pronounced an effect on reply efficiency as was observed with the AN/GRN-9C. In a few cases, nondecodable PDME signals that had a high PRF, moderate strength, and were separated by only one channel from the transponder allowed the RTB-2 to operate with 60% reply efficiency. In other tests in which the PDME signal had essentially the same characteristics, RTB-2 performance was markedly lower.

The reason for running several tests with the same PDME signals was to allow variations in two RTB-2 receiver parameters-multipath deadtime and deadtime triggering level. It is not unlikely that the difference in performance noted above was due in part to these variations. It was expected that the setting which produced more and/or longer intervals of deadtime would cause lower efficiency due to the inhibition of valid interrogations. No such pattern emerged, and the performance variations appeared random.

Test Equipment Irregularities

Disparities existed between typical reply efficiency levels that were obtained in Y-mode. The characteristics of the signals alone could not account for this disparity. The test setup was examined for a possible explanation. In X-mode operation, the Kustom Electronics SQUAWK/NAUT-I was used to produce PDME pulses (FIGURE 8). However, the SQUAWK/NAUT-I has a range of pulse-pair spacings which are adjustable only from 7 to 18 μ s, and from 24 to 36 μ s, and thus could not be used to produce pulse pairs with the 27 or 42 μ s spacings required for Y-mode testing. Accordingly, for this phase, the SQUAWK/NAUT-I became the generator for the desired signal (pulse-pair spacing 36 μ s), while the RTB-2 was used to produce simulated PDME pulses.

To confirm that the different setups were responsible for the discrepancy, a single series of tests was run in Y-mode, first using the RTB-2 to produce the desired signal and the SQUAWK/NAUT-I the undesired, then with the reverse configuration, all signal parameters remaining the same. In each case, the PDME signal had a nondecodable spacing of 30 μ s which, although not the spacing required by the test plan, was as far outside the decoder aperture as the required one and within the range of adjustment on both pieces of equipment. The results are shown in FIGURE 74. It can be seen that reply efficiency approaching 60% is obtainable with desired signals at MDS, and very high efficiency with signals at MDS + 6 dB, provided the standard test configuration utilizing the SQUAWK/NAUT-I for the PDME signals is used. This data is comparable to that obtained in the X-mode tests and in the test of Y-mode without interference. Using the SQUAWK/NAUT-I to produce the TACAN signal instead will not permit comparably high levels of efficiency to be obtained. This is probably due principally to the non-periodic nature of the pulse transmissions from the SQUAWK/NAUT-I, as described in Section 2.

This does not mean the results of Y mode testing are totally invalid. Presumably behavior within that mode is consistent, and valid inferences can be drawn regarding relative efficiency levels under various test conditions.

Summary of Observations for TACAN Transponders

The principal causes of reduced efficiency in the TACAN transponders tested are:

1. Reduced sensitivity due to overload, occurring when the PRF of the decodable PDME signals is high enough to cause reply rate limiting.
2. Decoder-generated deadtime caused by the presence of a PDME pulse-pair with spacing inside the decoder aperture.
3. Multipath (echo suppression) deadtime caused by strong, non-decodable PDME signals.

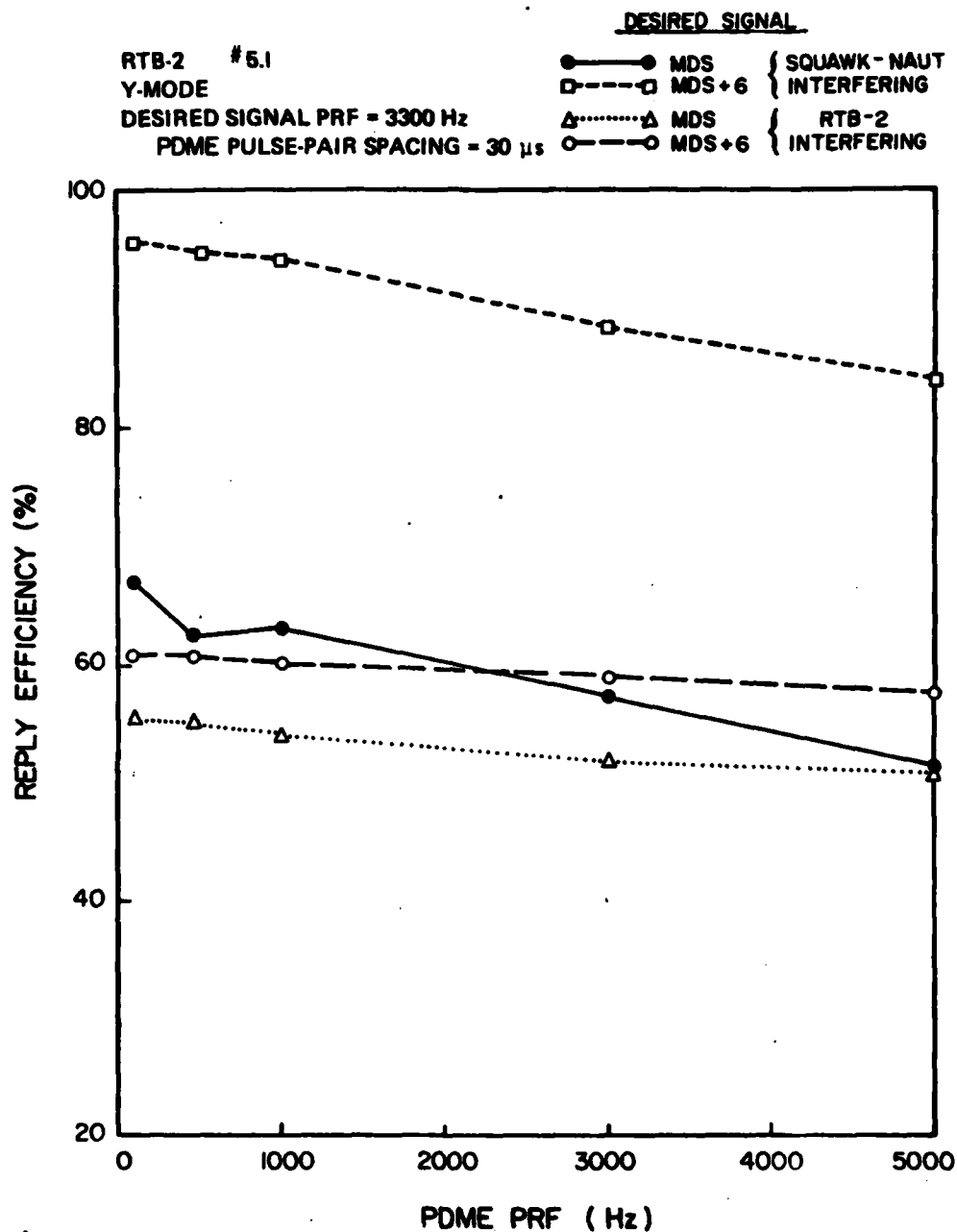


FIGURE 74. RTB-2 Y-MODE PERFORMANCE IN THE PRESENCE OF PDME SIGNALS.

From the results of X-mode testing it was clearly observed that decodability of the PDME pulse pairs (12 μ s spacing) had a more devastating effect on transponder efficiency than any other single characteristic, reducing efficiency to 15% or less in many cases. Effects of nondecodable signals were seen principally in adjacent channels where decodability is not a factor because the actual signals are prevented from reaching the decoder by the selectivity of the Ferris discriminator. Based on the test data, it appears proper channel separation is the most effective method for maintaining the desired reply efficiency performance of TACAN transponders.

The true effect of interference in adjacent channels can be seen in FIGURE 75. The reduction in efficiency is small so long as the strength of the PDME signals is below a certain point; above that point it is marked. This "break point," corresponding approximately to the off-frequency rejection characteristics of the receiver in the presence of PDME signals, increases in value with increased frequency separation. Four channels away it occurs at a PDME signal level nearly 50 dB above MDS. However, it cannot be said that TACAN performance is totally free of the effects from PDME signals unless the separation between the desired and undesired signals is at least five channels (5 MHz). Since interference protection of TACAN transponders is not a requirement bearing on PDME channel assignment at this time, no recommendations are made based on this observation.

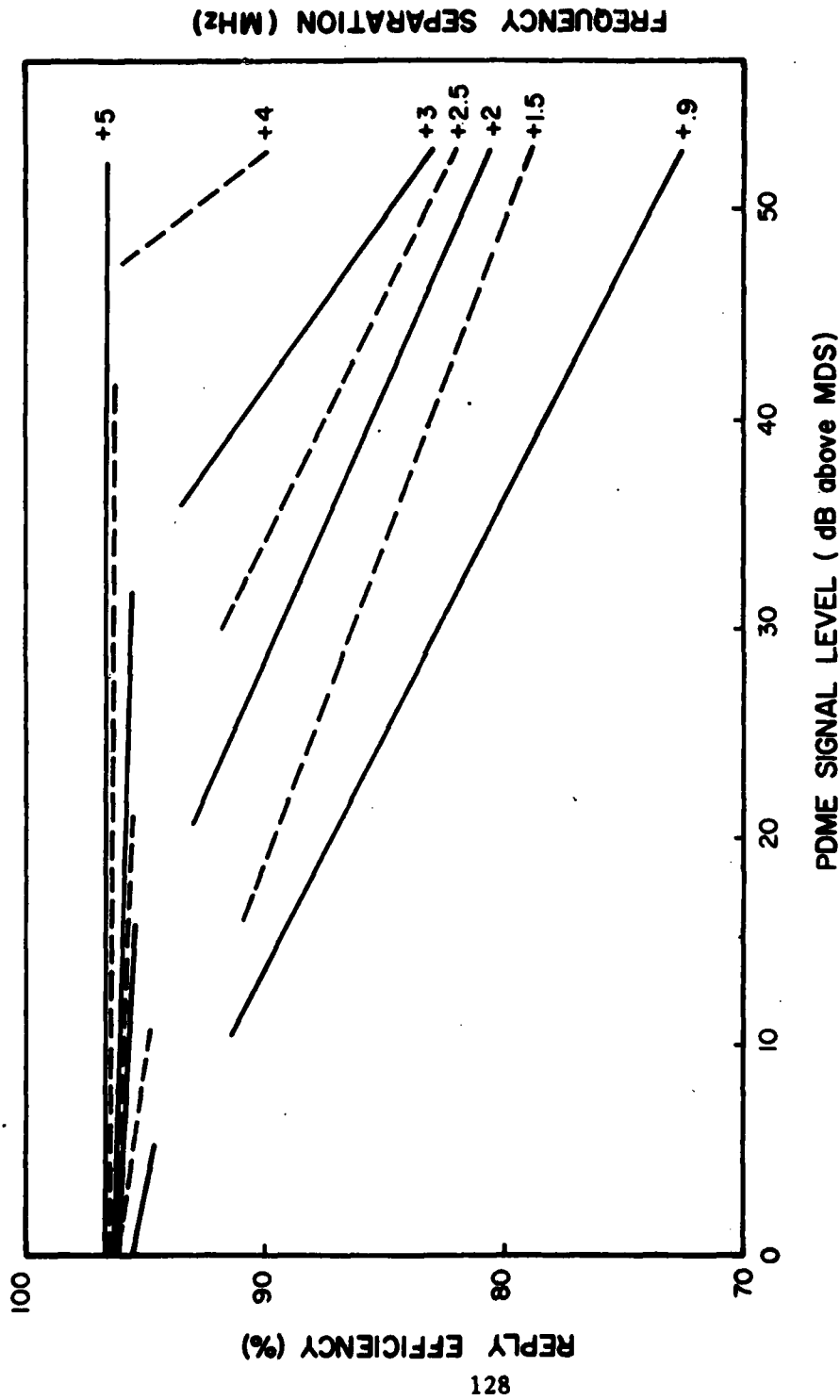


FIGURE 75. RTB-2 ADJACENT-CHANNEL PERFORMANCE IN THE PRESENCE OF PDME SIGNALS.

SECTION 4

SUGGESTIONS FOR FURTHER ANALYSIS AND MEASUREMENT

The feasibility of employing L-Band (960-1215 MHz) for the PDME subsystem of the international nonvisual precision approach and landing system depends on:

1. Satisfying the PDME accuracy requirements
2. Intrasytem EMC
3. Intersystem EMC with TACAN/DME and secondary surveillance radar
4. Channel availability.

The measurements and results discussed in this report form the initial attempt to investigate the latter two items with regard to PDME-to-TACAN/DME compatibility. The next step in the investigation is to verify or amend the conclusions of this report by conducting a more intensive measurement and analysis program. Further, the FAA should begin investigation of intrasystem and TACAN-to-PDME compatibility.

INTERROGATORS

The measurements indicate that decodability of the PDME signal is not a factor in the susceptibility of some interrogators to the interfering pulse pairs. This is a result that was not expected and requires further investigation. It would be helpful to test other equipments such as the AN/ARN-118, the COLLINS 860-E5, and the NARCO DME 195 and also to test several KING KDM 7000, NARCO DME 190 and AN/ARN-84 interrogators. The future tests should be designed to verify or disprove the previous test data and to determine the reasons for the behavior obtained in these tests.

The adjacent-channel susceptibility of some interrogators appeared to be worse by more than the differences in the TACAN and PDME pulse spectra. To indicate more closely the differences in susceptibility of the interrogators, tests could be performed to determine TACAN interrogator susceptibility as a

function of TACAN pulse pairs. Comparing the results with the measured data for PDME pulse pairs would show the difference in effect of two signal formats.

The measurements performed thus far consider only a single interfering signal. More detailed measurements should be performed using cochannel and adjacent frequency desired and undesired signals. Undesired signals should consist of both TACAN and PDME pulse pairs to simulate a more realistic signal environment.

The performance of some interrogators in the presence of decodable and nondecodable PDME pulse pairs shows that there are signal conditions under which nondecodable pulse pairs can disrupt TACAN operation. This leads to the question of whether X-mode interrogations can impact the operation of Y-mode interrogators. An analysis and measurement program should examine this question. Presently, no siting criteria is imposed between X-mode and Y-mode equipments as a function of air-to-air interference.

TABLE 10 lists the limiting conditions for which TACAN/DME interrogators will acquire lock in the presence of PDME pulse pairs. The question of concern to FAA is whether these conditions will permit assignment of PDME channels. The suggestion here is to perform a channel assignment analysis to see how these conditions effect PDME channel assignability. Also, the analysis could determine the conditions necessary to permit the flexibility in PDME required for MLS installation. A channel assignment analysis should be included that considered the assignment of both angle- and range-guidance channels. This investigation would show which function, range or angle limited the deployment of MLS and how channel pairings affected channel availability.

TRANSPONDERS

The examination of the test data obtained for the AN/GRN-9C and RTB-2 transponders suggests that much further testing and analysis is required before any definite guidelines can be established for PDME channel assignment. Specifically, the following recommendations are made for the conduct of further study:

The transponders tested by NAPEC are not representative of those in actual use, due to the presence or lack of important modifications, so that the validity of test results is questionable at best. It is recommended that further testing be carried out using field models of the AN/GRN-9C, RTB-2, and ILS-DME's that are more representative of operational equipment. The specific effects of the retriggerable blanking gate should be measured and investigated in detail.

It is suggested that MDS used for testing be based on a reply efficiency of 70% rather than 60%. While the actual signal level would differ only 2 or 3 dB, this would make test conditions consistent with the national standard for the VORTAC System (Reference 10).

Further study should be made of the estimated likelihood of the two "uncontrollable" MLS signal characteristics--PRF and signal strength. Distribution of signal strengths was incorporated into some of the analysis already done, but more investigation would be useful in defining a realistic interference situation.

SECTION 5

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

1. TACAN/DME interrogators and transponders are susceptible to interference in the form of PDME pulse pairs. Susceptibility increases as a function of PDME pulse-pair repetition rate.

2. Those interrogators and transponders most susceptible to the interference showed little variance in susceptibility as a function of PDME pulse-pair spacing.

3. For the loading conditions tested, the minimum desired-to-undesired signal conditions permitting TACAN/DME interrogators to acquire lock in the presence of PDME signals were comparable to or more stringent than the existing one-on-one criteria applied to protect TACAN/DME from intrasystem interference.

4. Contrary to common opinion, existing TACAN/DME interrogators and transponders are not capable of providing sufficient rejection of undesired signals with a high PRF typical of an environment comprised of pulse-multi-plexed equipment.

5. Based on the measured data, the previously proposed channel plans do not provide 200 separate and distinct channels. Assigning these channels in a mixed environment appears no easier than assigning the existing TACAN/DME channels.

RECOMMENDATIONSInterrogators

It is recommended that:

1. The reasons for susceptibility of the KING KDM 7000 and the AN/ARN-84 to PDME decodable and nondecodable pulse pairs be determined.

2. Measurements be performed on other newer interrogators, such as the AN/ARN-118, COLLINS 860-E5, and NARCO DME 195.

3. Measurements be performed using normal TACAN pulse pairs so that interrogator performance in the presence of TACAN/DME signals can be compared to performance in the presence of PDME signals.

4. Measurements be performed using multiple TACAN/DME and PDME undesired signals. This would provide a more realistic background signal environment.

5. Measurements and analyses be performed to determine the mutual electromagnetic compatibility of X-mode and Y-mode equipments.

6. A channel assignment analysis be conducted to ascertain how the PDME vs TACAN/DME signal conditions discussed in this report affect PDME channel assignability. The analysis should include the impact of assigning both angle and range channels and a determination of the limiting conditions on assignability.

Transponders

It is recommended that:

1. Measurements be performed on field models of the AN/GRN-9C, RTB-2, and Instrument Landing System (ILS)-DME transponders. As part of this measurement program, the specific effects of the retriggerable blanking gate should be investigated.

2. An analysis be performed to determine the most likely PDME PRF and signal strength levels that would degrade transponder performance. This would serve to evaluate realistic interference situations.

APPENDIX A
DATA SHEETS FOR THE AN/ARN-21C

This appendix provides the cochannel and adjacent-channel azimuth and/or range performance data as well as decoder aperture data for the AN/ARN-21C.

In the cochannel case, the MLS-DME signal level that allows the AN/ARN-21C to acquire lock and also the level that causes it to break lock (for the desired signal level specified at the top of the table) are given for various MLS-DME pulse-pair spacings and PRF's. In addition, for PRF's of 2700 and 5000 Hz, the magnitude of the MLS-DME signal level required to effect lock as a function of desired signal level is provided. For both MLS DME and TACAN/DME, the decoder aperture is presented in terms of number of decodes.

The acquire- and break-lock measurements are repeated for adjacent-channel conditions of four different frequency separations between the MLS DME and the TACAN/DME. These measurements were made for only two values of PRF and pulse-pair spacings.

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